Limitations of the Green's function approach to analyzing spatial radiative feedbacks

Jonah Bloch-Johnson, Maria Rugenstein, Jonathan Gregory

CFMIP 2019 - 1.10.19

multiple regression

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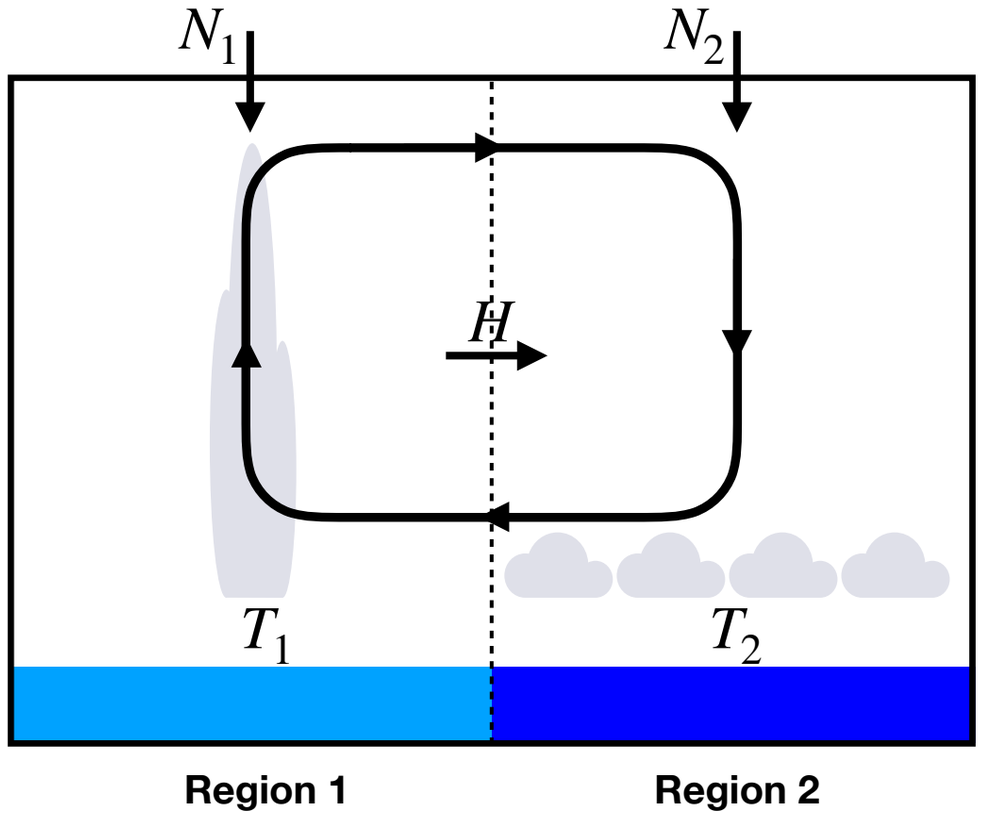
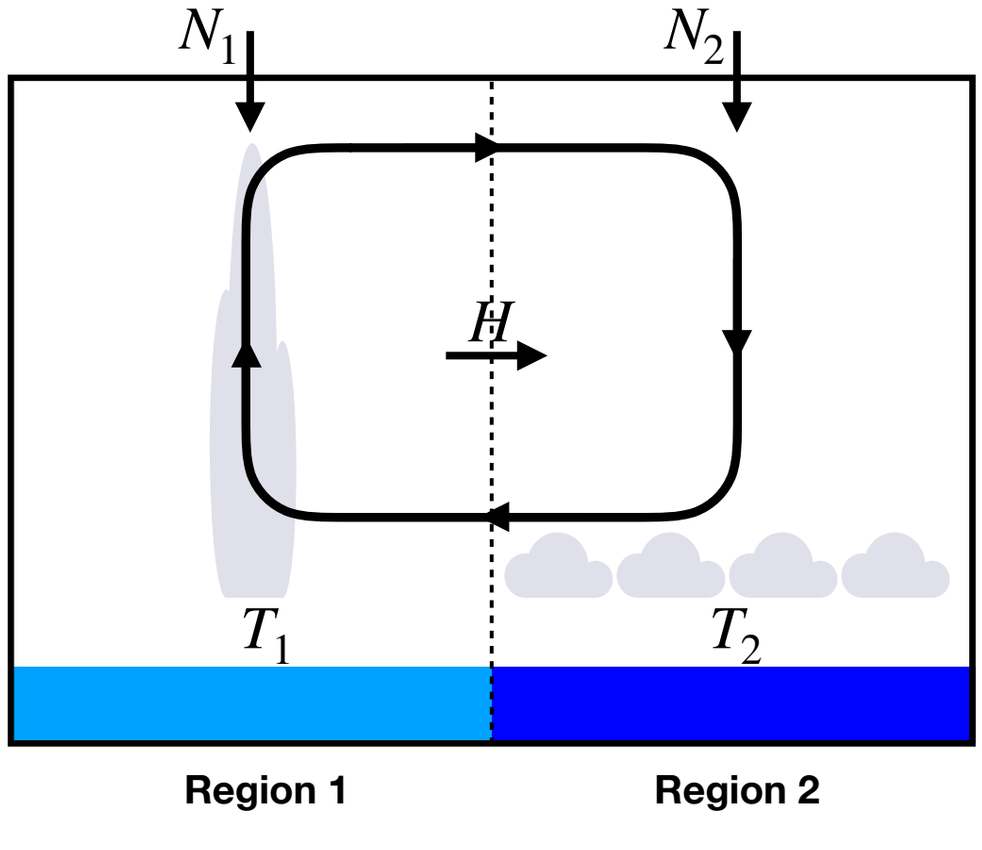
Multiple regression approach is a method for estimating spatial feedbacks from internal variability

Multiple regression approach is a method for estimating spatial feedbacks from internal variability

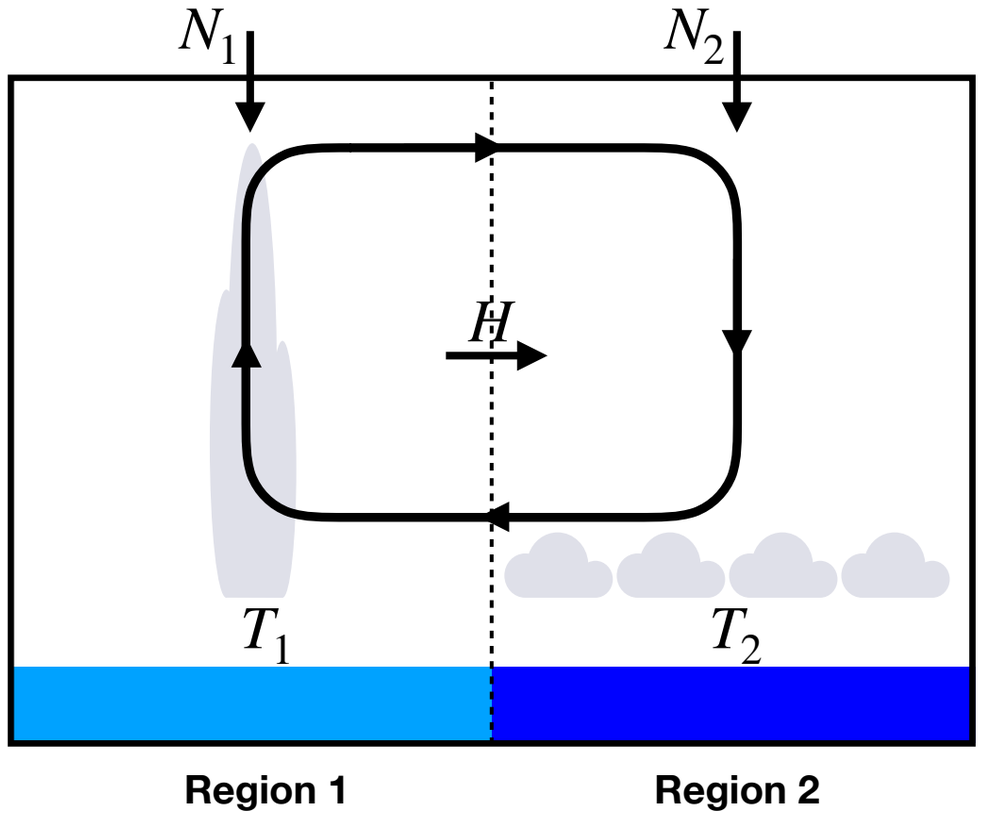
Long-term goal:
observationally-based
forecast of warming that
accounts for the pattern effect


N_1
N_2
H
T_1
T_2
Region 1
Region 2



$$c_1 \frac{dT_1}{dt} = N_1 - H + F_{surf,1}$$

$$c_2 \frac{dT_2}{dt} = N_2 + H + F_{surf,2}$$

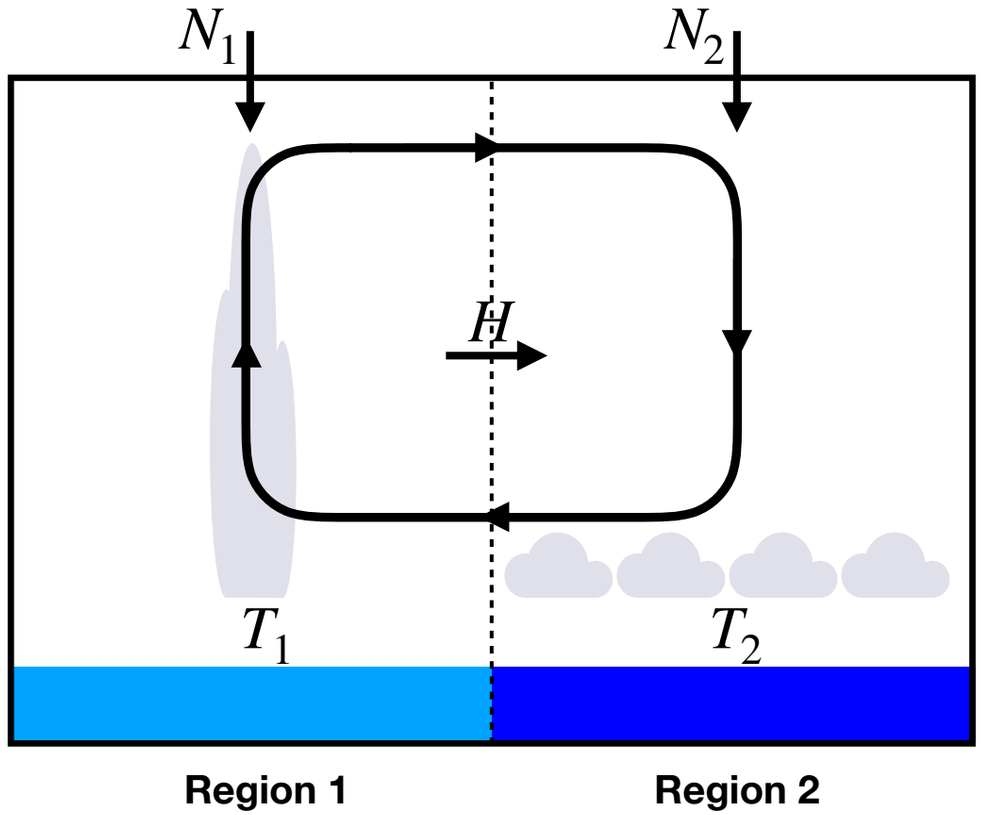


$$c_1 \frac{dT_1}{dt} = N_1 - H + F_{surf,1}$$

$$c_2 \frac{dT_2}{dt} = N_2 + H + F_{surf,2}$$

$$N_1 = \lambda_{1,1} T_1 + \lambda_{1,2} T_2 + F_{TOA,1} + F_{CO_2,1}$$

$$N_2 = \lambda_{2,1} T_1 + \lambda_{2,2} T_2 + F_{TOA,2} + F_{CO_2,2}$$



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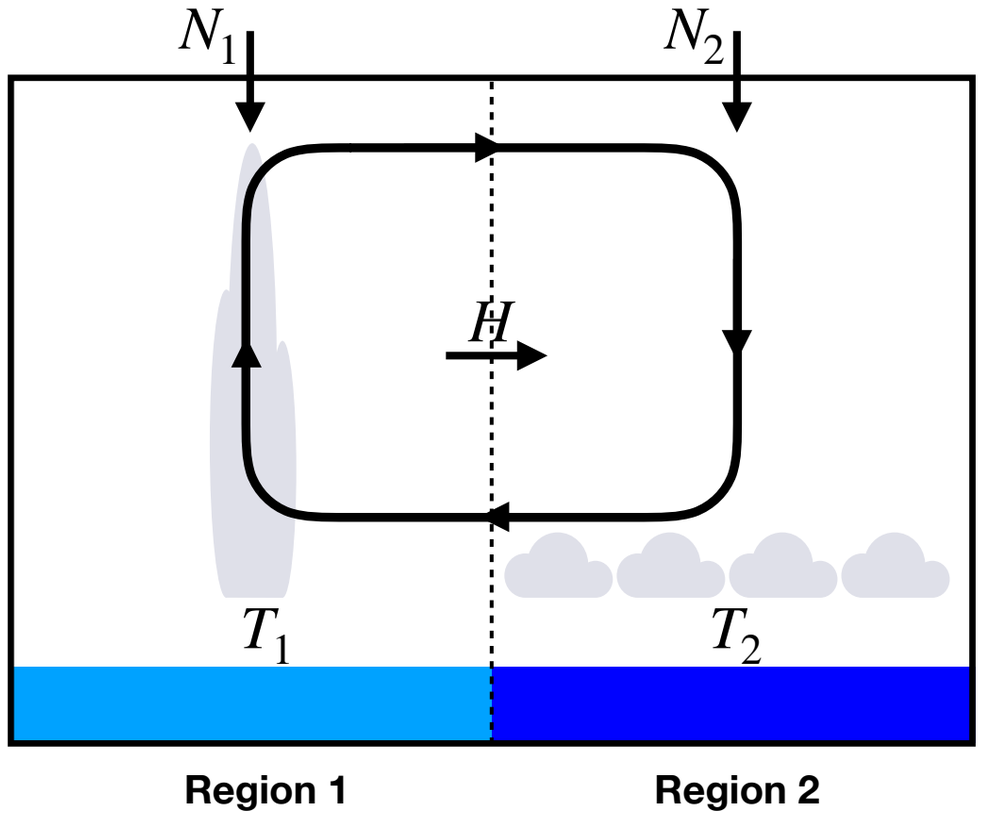
Rose and Rayborn 2016
Andrews and Webb 2017
Ceppi and Gregory 2017

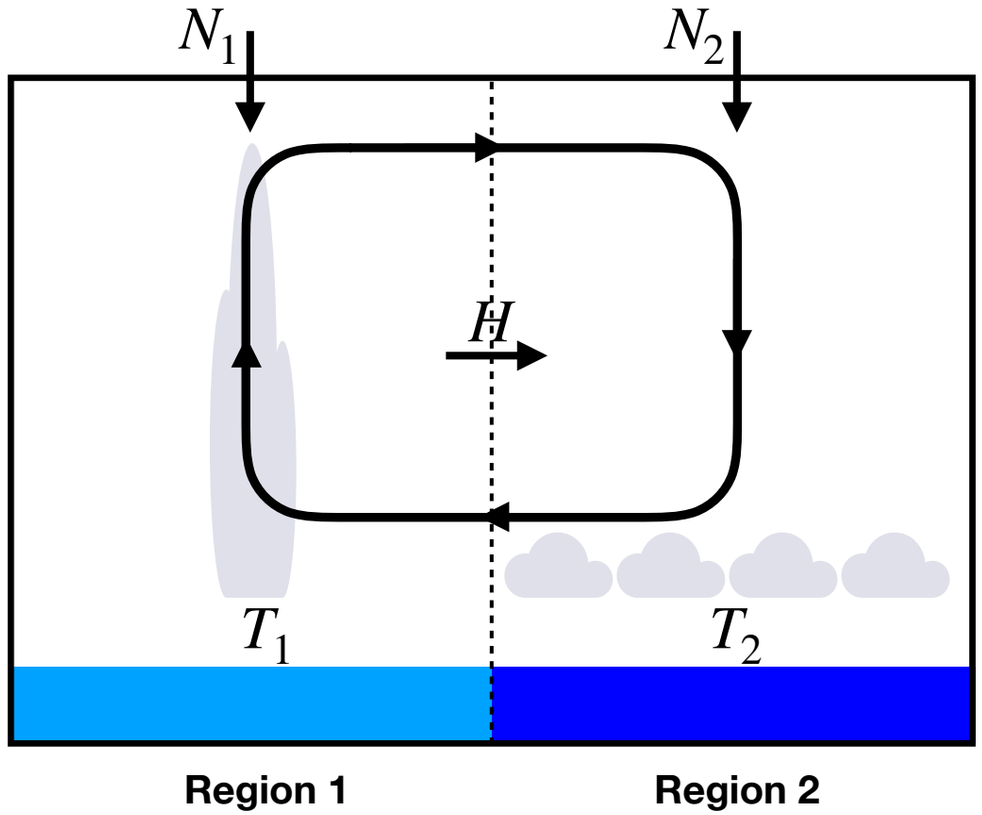
Klein et al. 2017
Zhou et al. 2017
Dong et al. 2019



$$c_1 \frac{dT_1}{dt} = N_1 - H + F_{surf,1}$$

$$c_2 \frac{dT_2}{dt} = N_2 + H + F_{surf,2}$$

$$\vec{N} = \Lambda \vec{T} + \vec{F}_{TOA} + \vec{F}_{CO_2}$$



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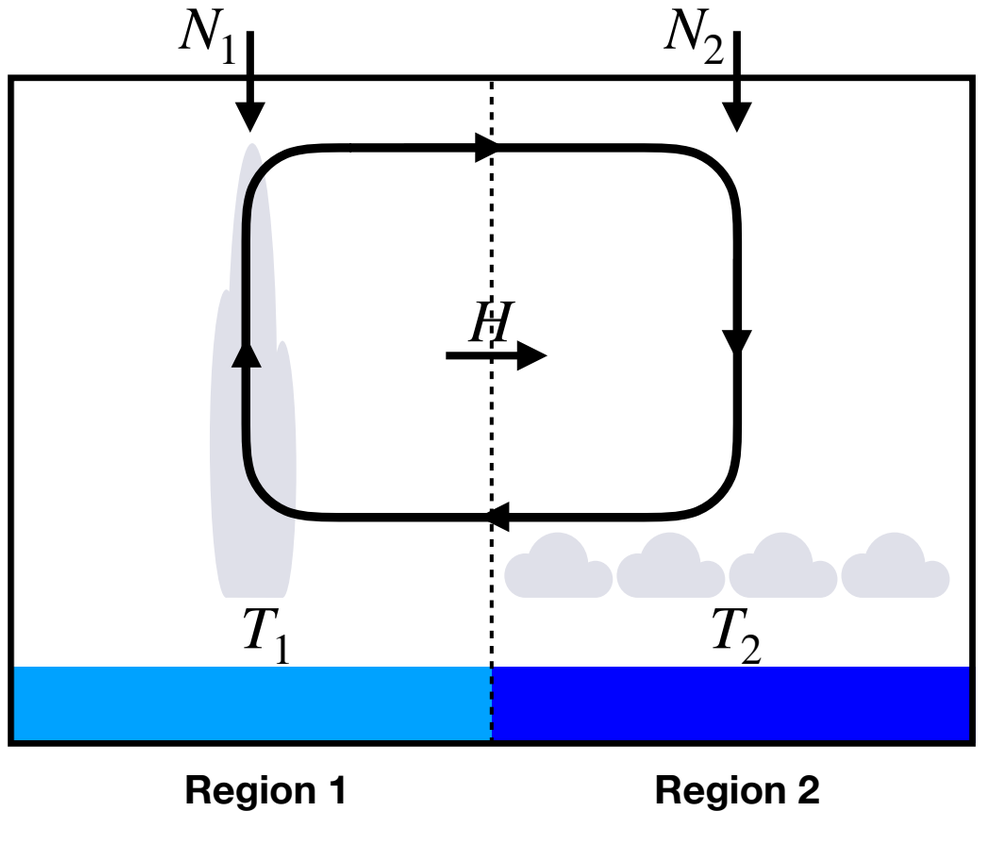
$$c_2 \frac{dT_2}{dt} = N_2 + H + F_{surf,2}$$

$$\vec{N} = \Lambda \vec{T} + \vec{F}_{TOA} + \cancel{\vec{F}_{CO_2}}$$



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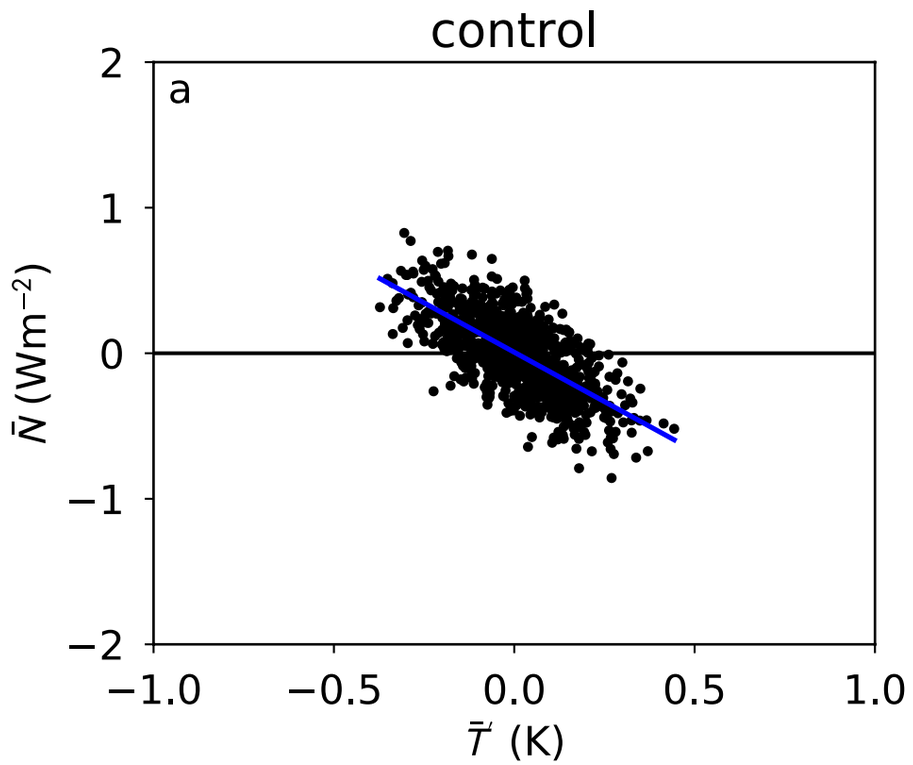
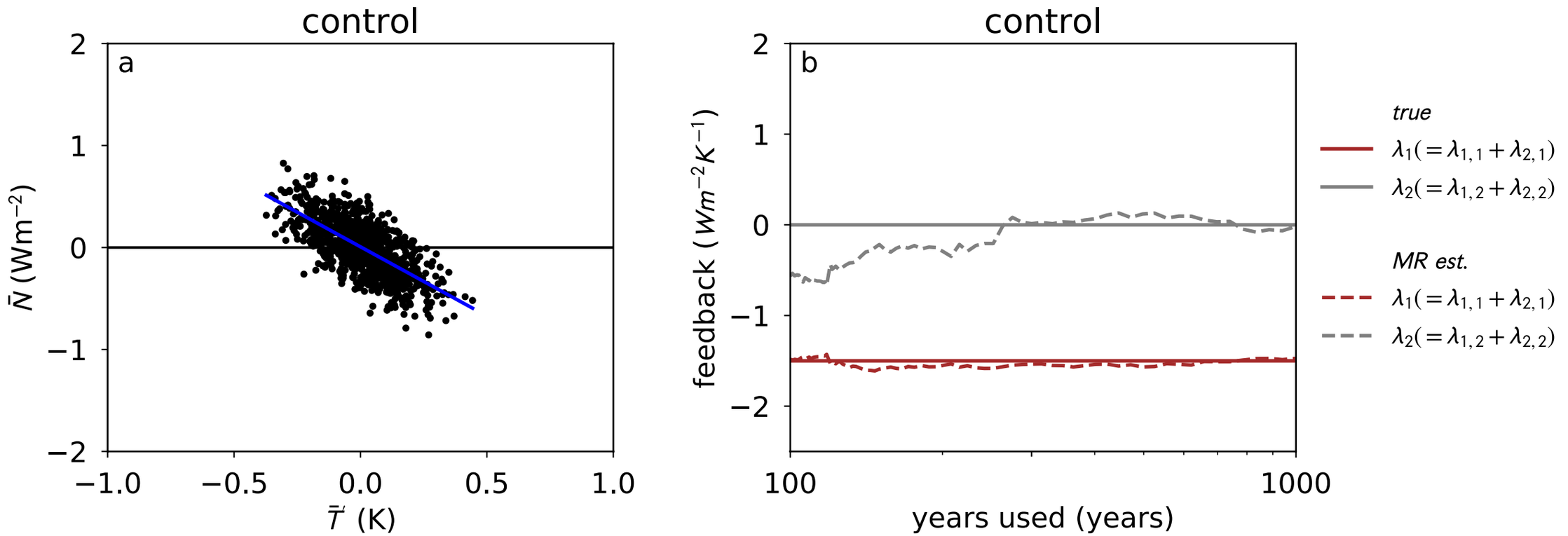
$$c_2 \frac{dT_2}{dt} = N_2 + H + F_{surf,2}$$

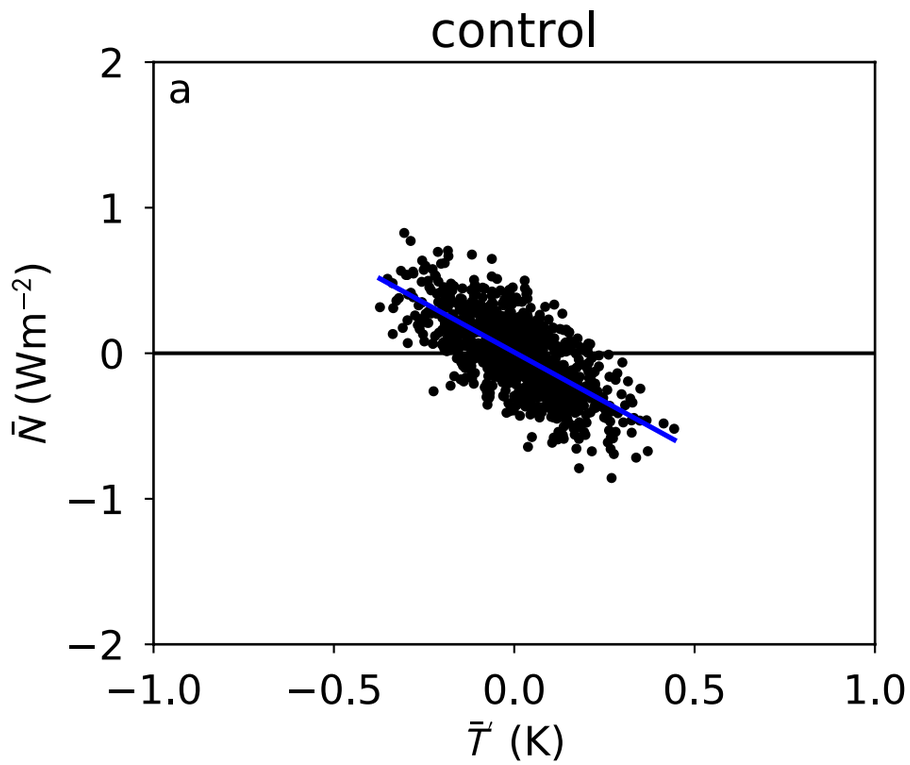
$$\vec{N} = \Lambda \vec{T} + noise$$

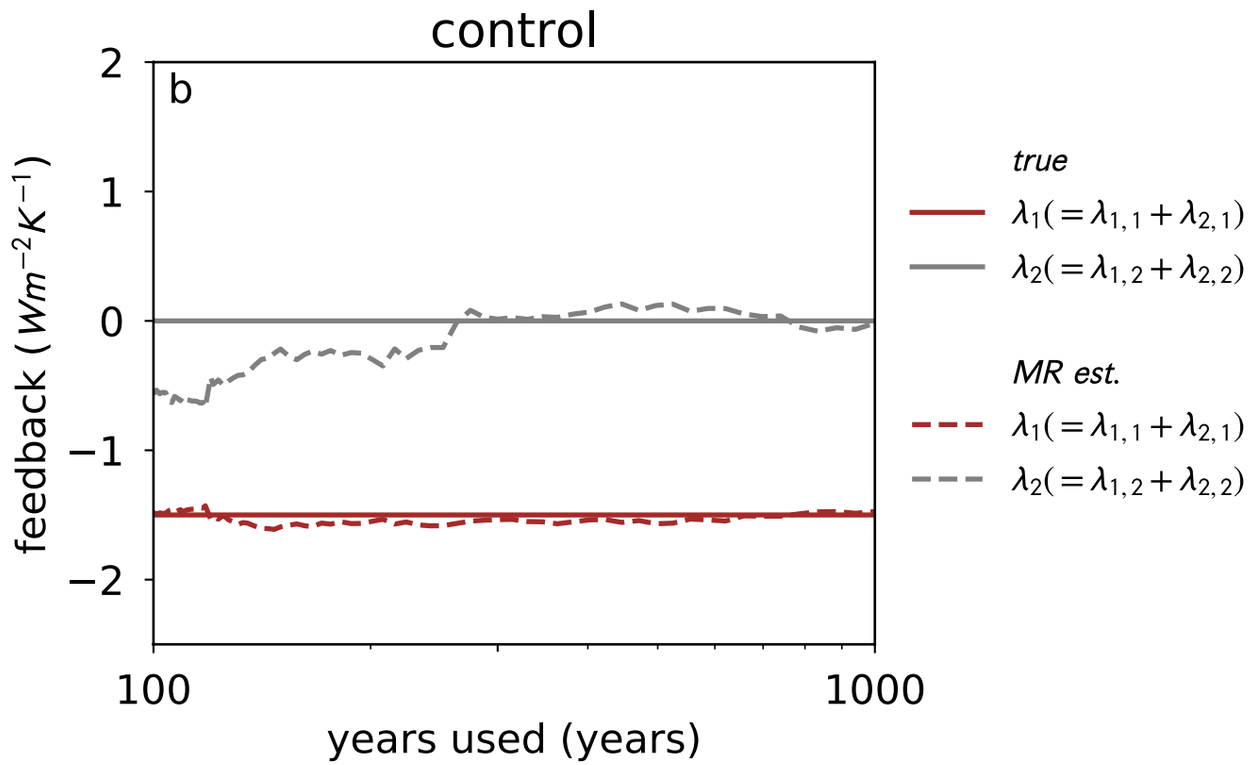


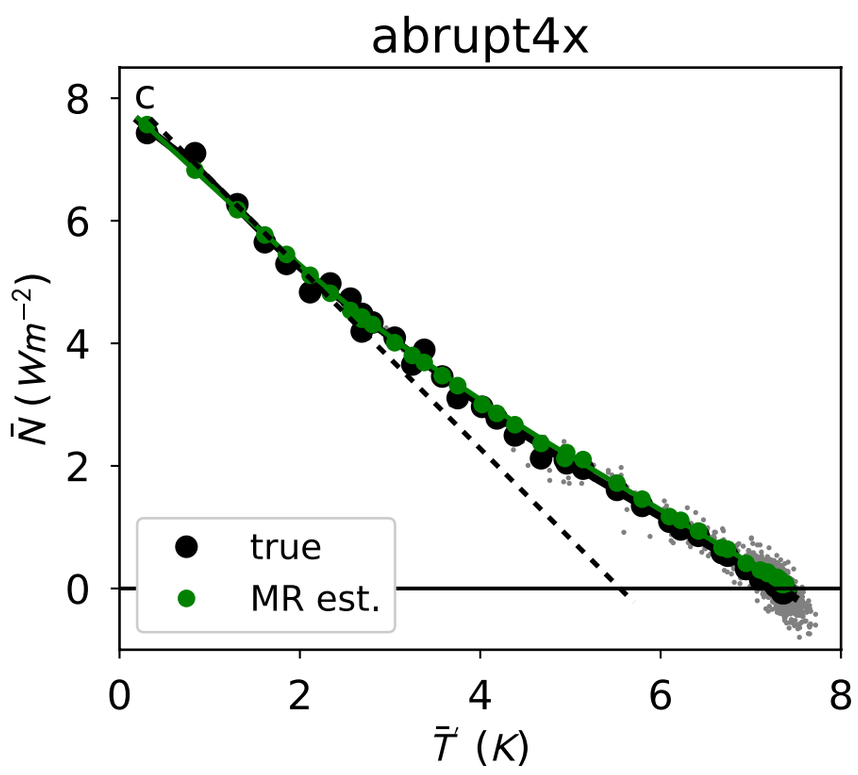
$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

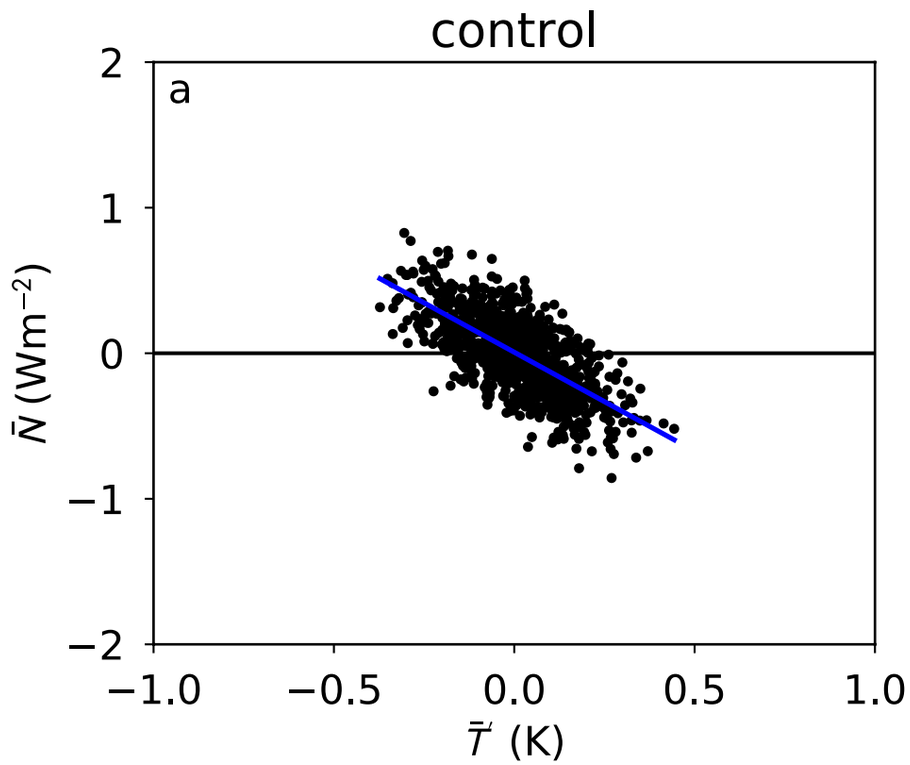


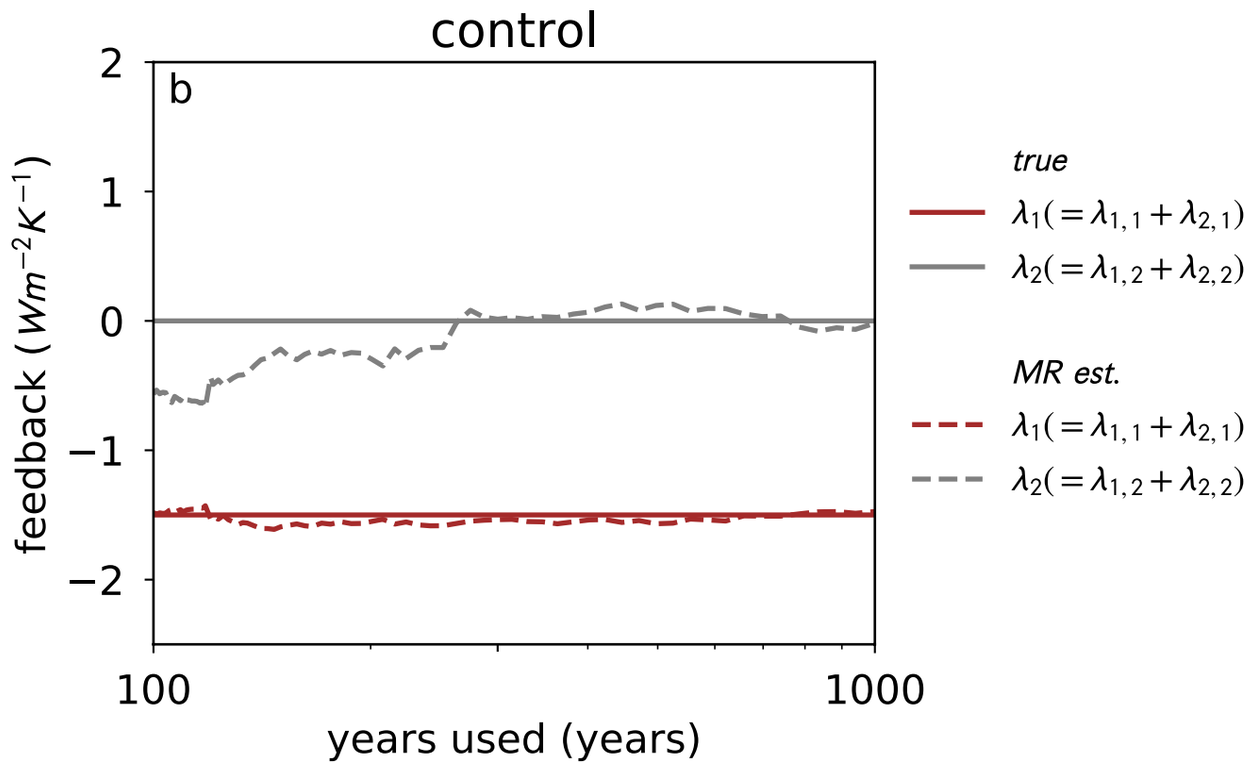
$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

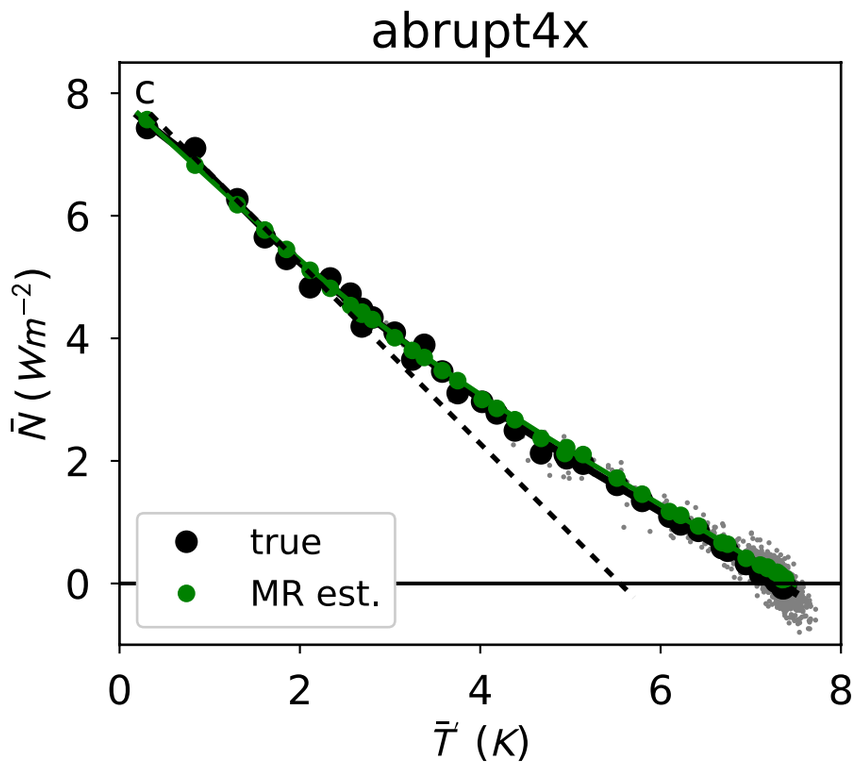

control
a
2
1
0
−1
−2
−1.0
−0.5
0.0
0.5
1.0
$\bar{N}$ (Wm^{-2})
$\bar{T}'$ (K)

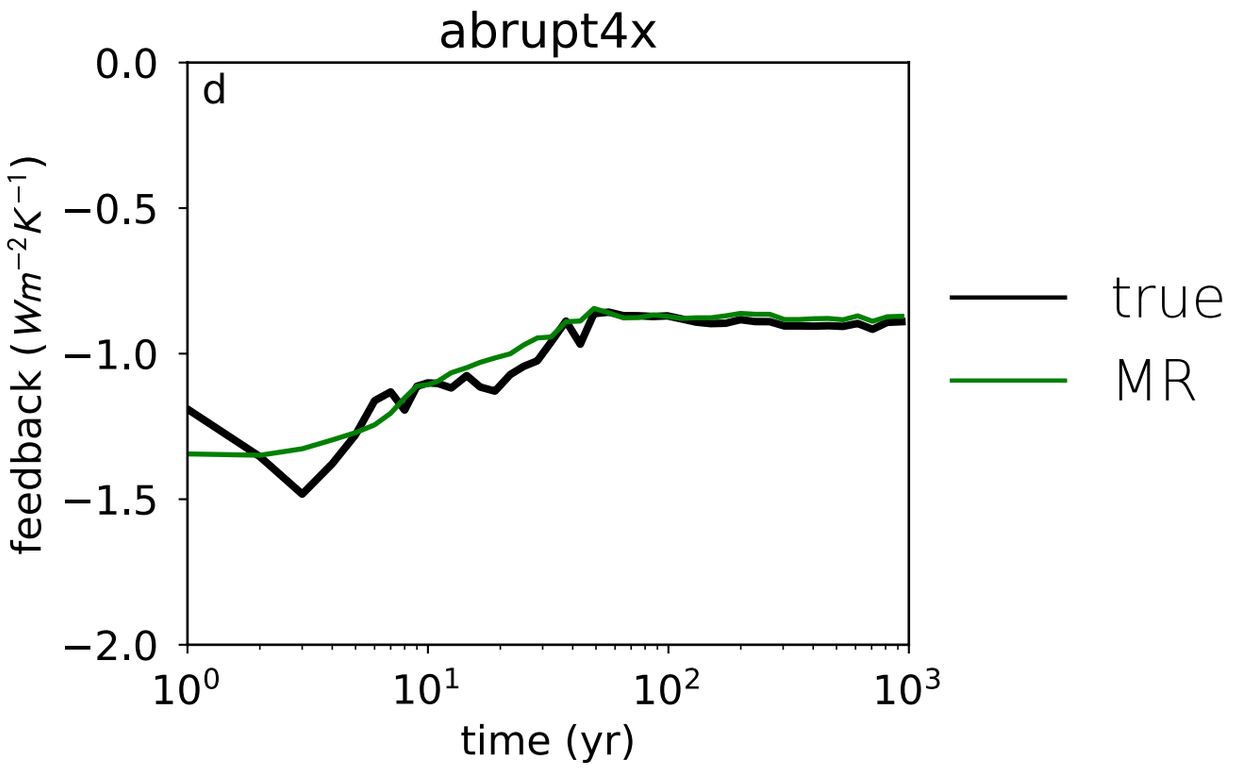

control
b
2
1
0
−1
−2
100
1000
feedback ($Wm^{-2}K^{-1}$)
years used (years)
true
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$
MR est.
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$

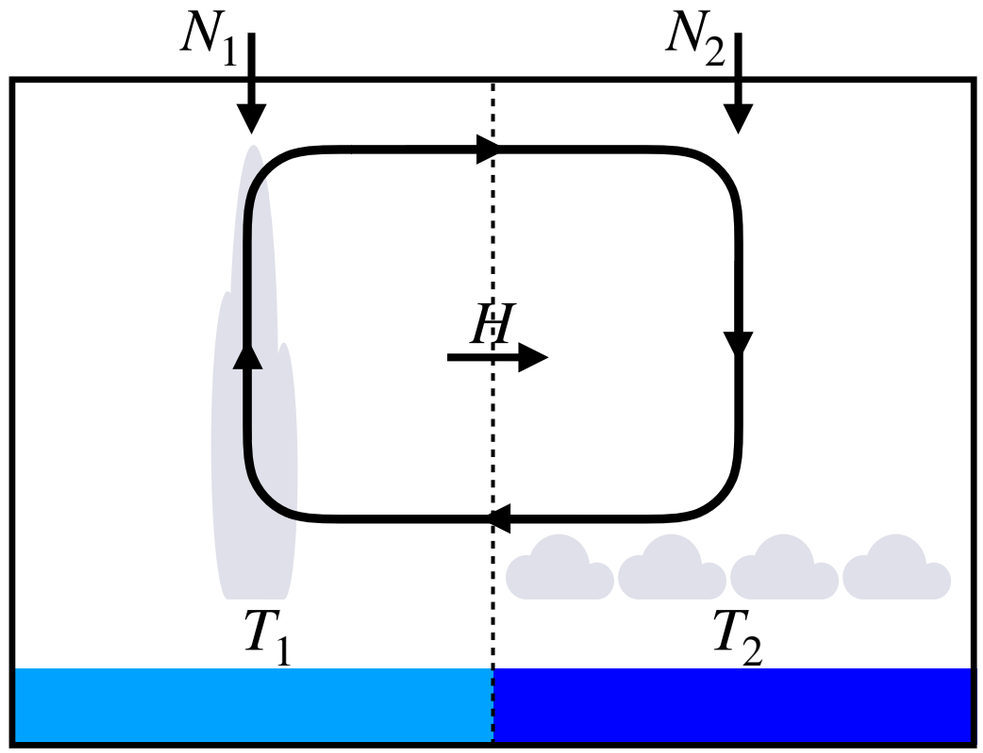

abrupt4x
c
8
6
4
2
0
0
2
4
6
8
$\bar{N}$ (Wm^{-2})
$\bar{T}'$ (K)
true
MR est.


control
a
2
1
0
−1
−2
−1.0
−0.5
0.0
0.5
1.0
$\bar{N}$ (Wm^{-2})
$\bar{T}$ (K)

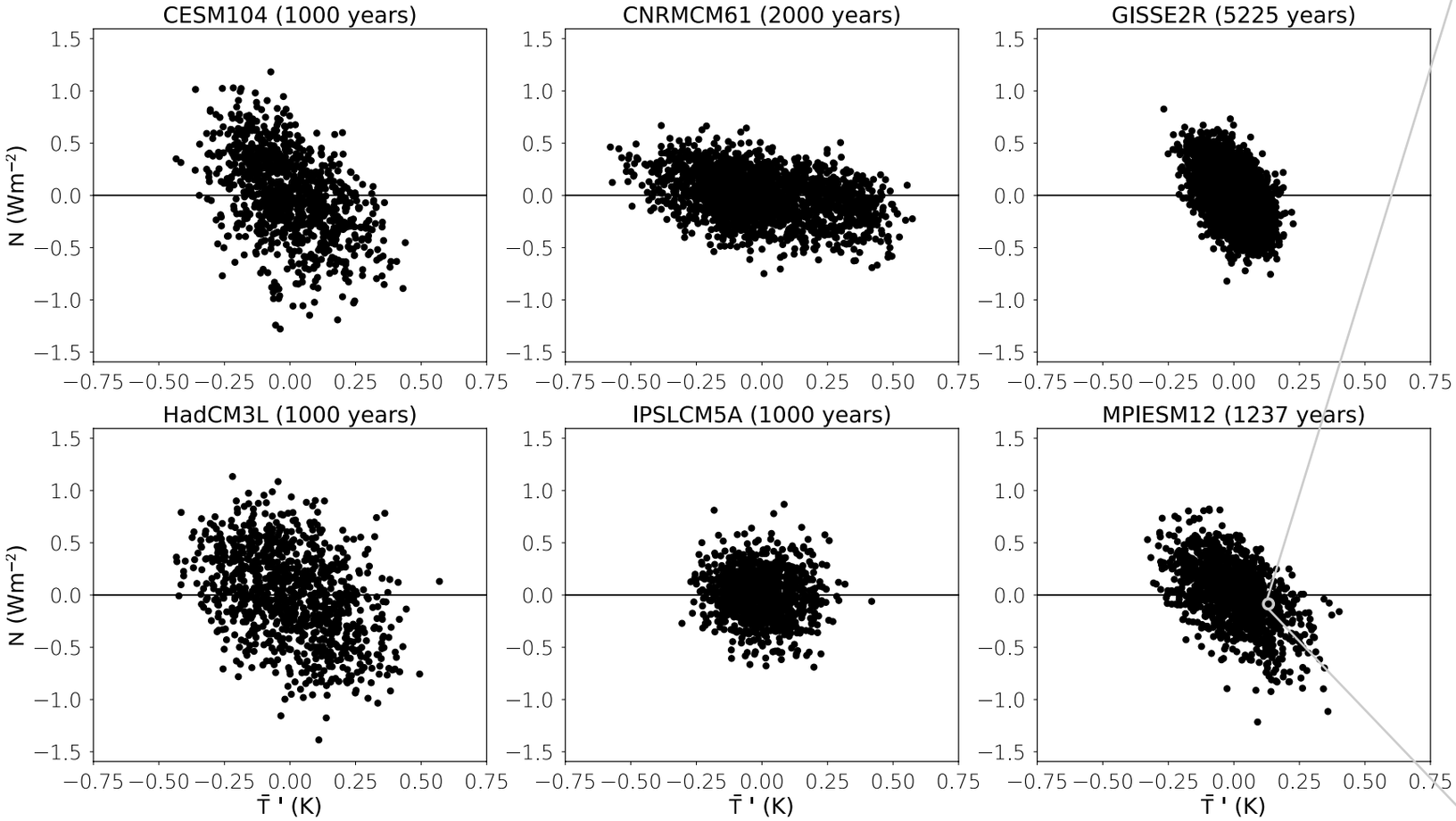

control
b
2
1
0
−1
−2
100
1000
feedback ($Wm^{-2}K^{-1}$)
years used (years)
true
$\lambda_1(=\lambda_{1,1}+\lambda_{2,1})$
$\lambda_2(=\lambda_{1,2}+\lambda_{2,2})$
MR est.
$\lambda_1(=\lambda_{1,1}+\lambda_{2,1})$
$\lambda_2(=\lambda_{1,2}+\lambda_{2,2})$

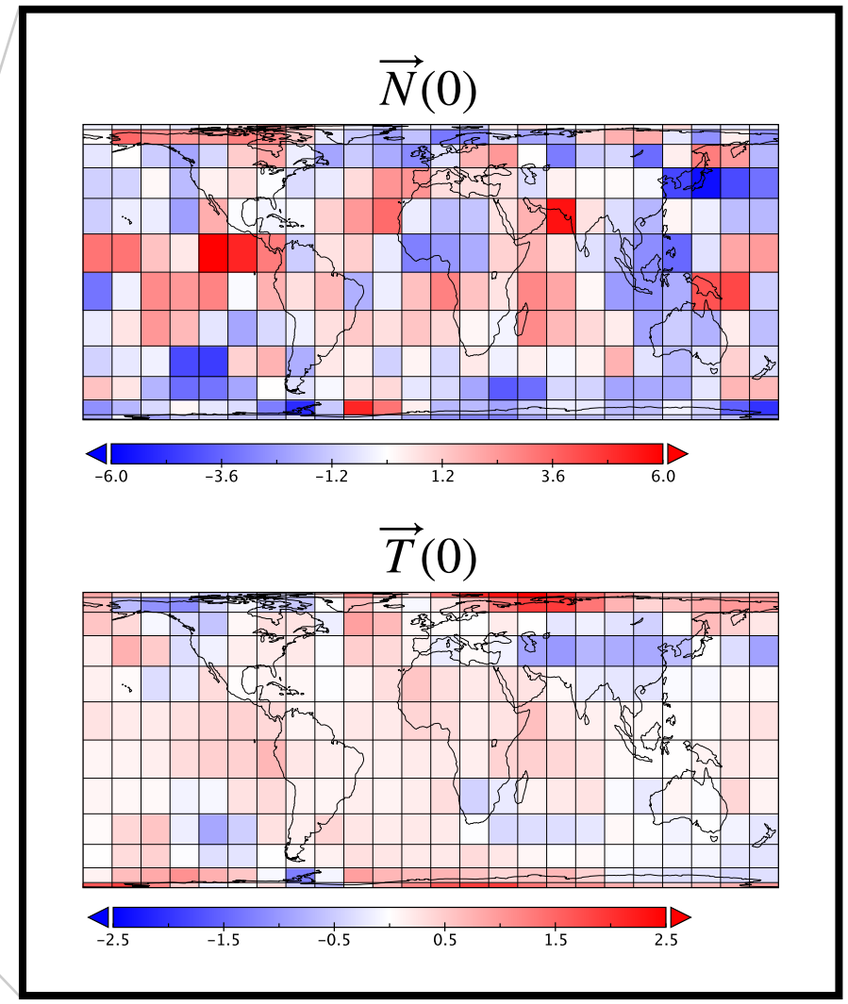

abrupt4x
c
8
6
4
2
0
0
2
4
6
8
$\bar{N}$ (Wm^{-2})
$\bar{T}$ (K)
true
MR est.


abrupt4x
d
0.0
−0.5
−1.0
−1.5
−2.0
10^0
10^1
10^2
10^3
feedback ($Wm^{-2}K^{-1}$)
time (yr)
true
MR



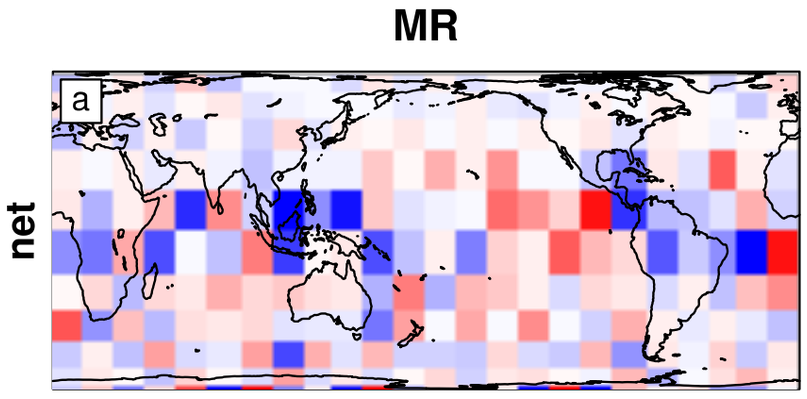
$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

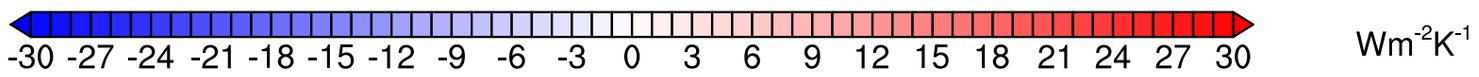




$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

LongRunMIP, Rugenstein et al., 2019



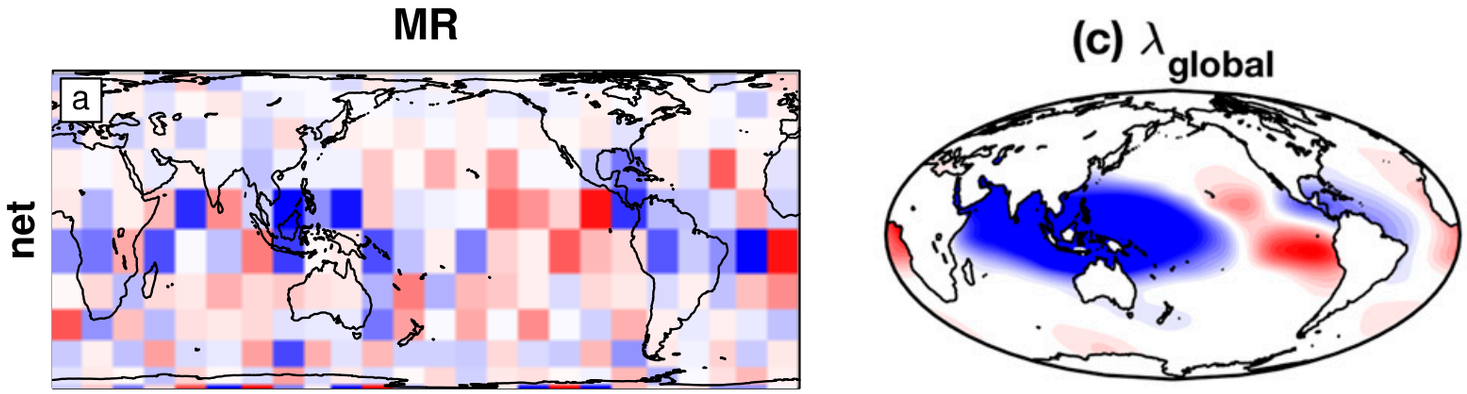


$$\vec{N} = \Lambda \vec{T} + noise$$

Dong et al., 2019

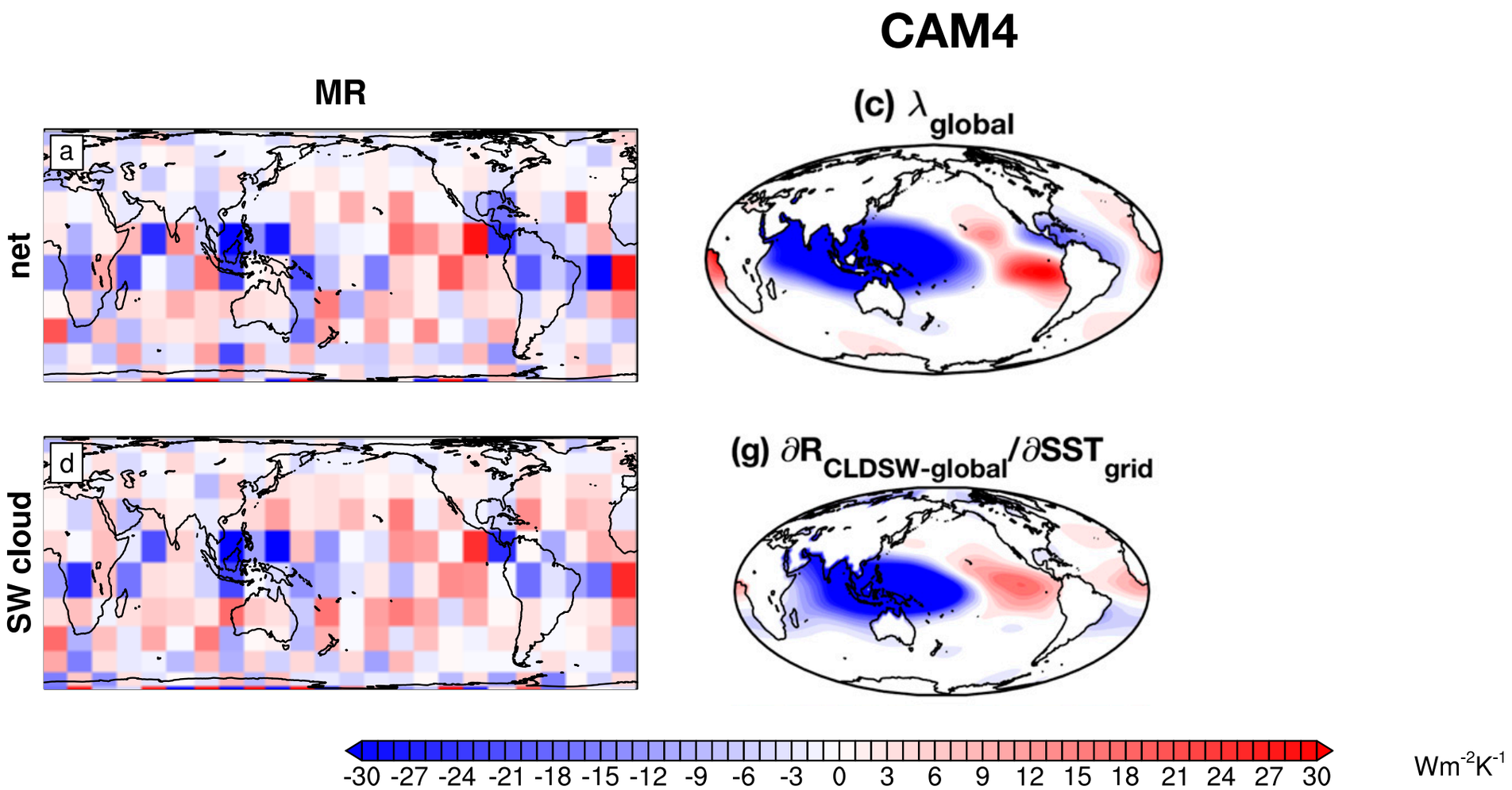
CAM4

MR

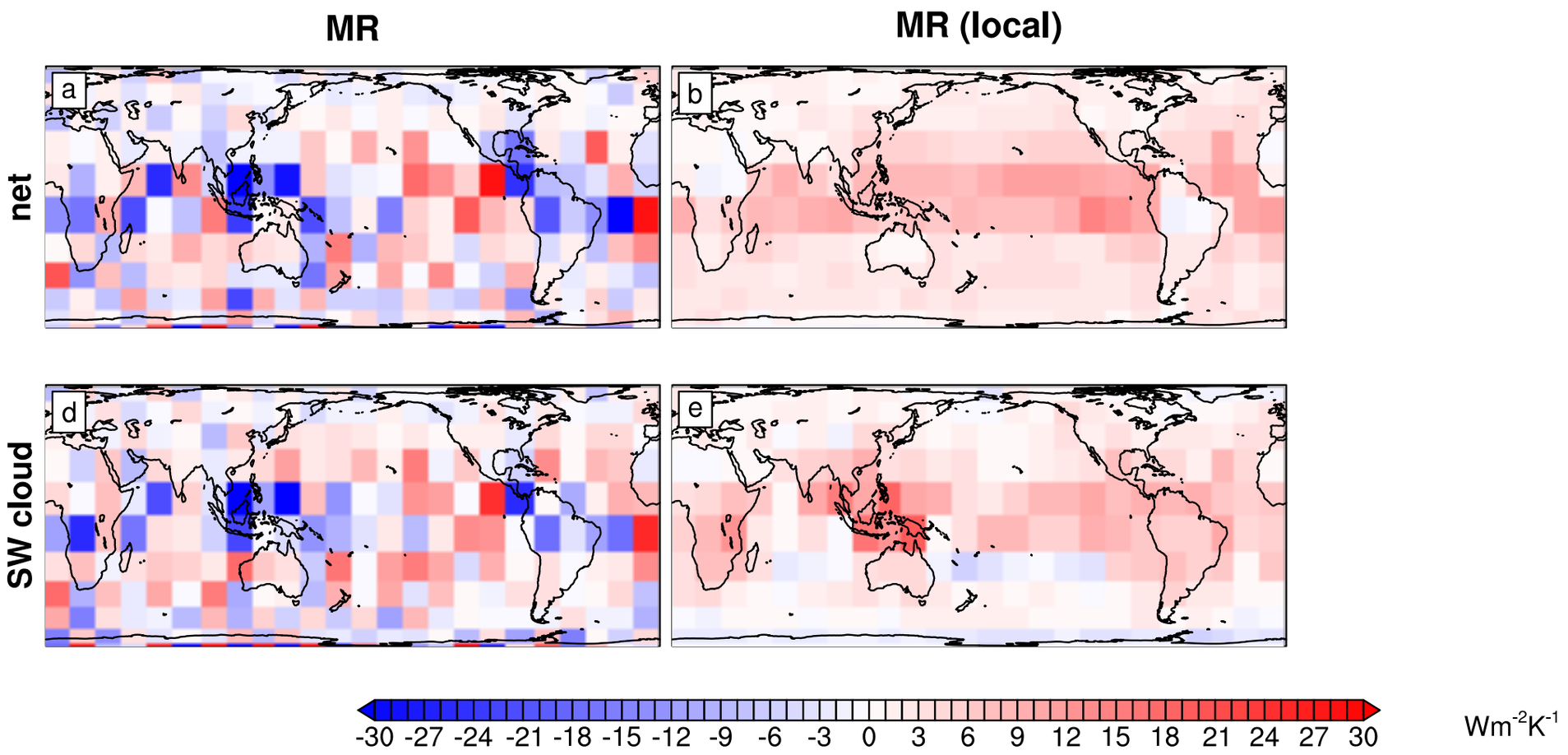


$$\vec{N} = \Lambda \vec{T} + noise$$

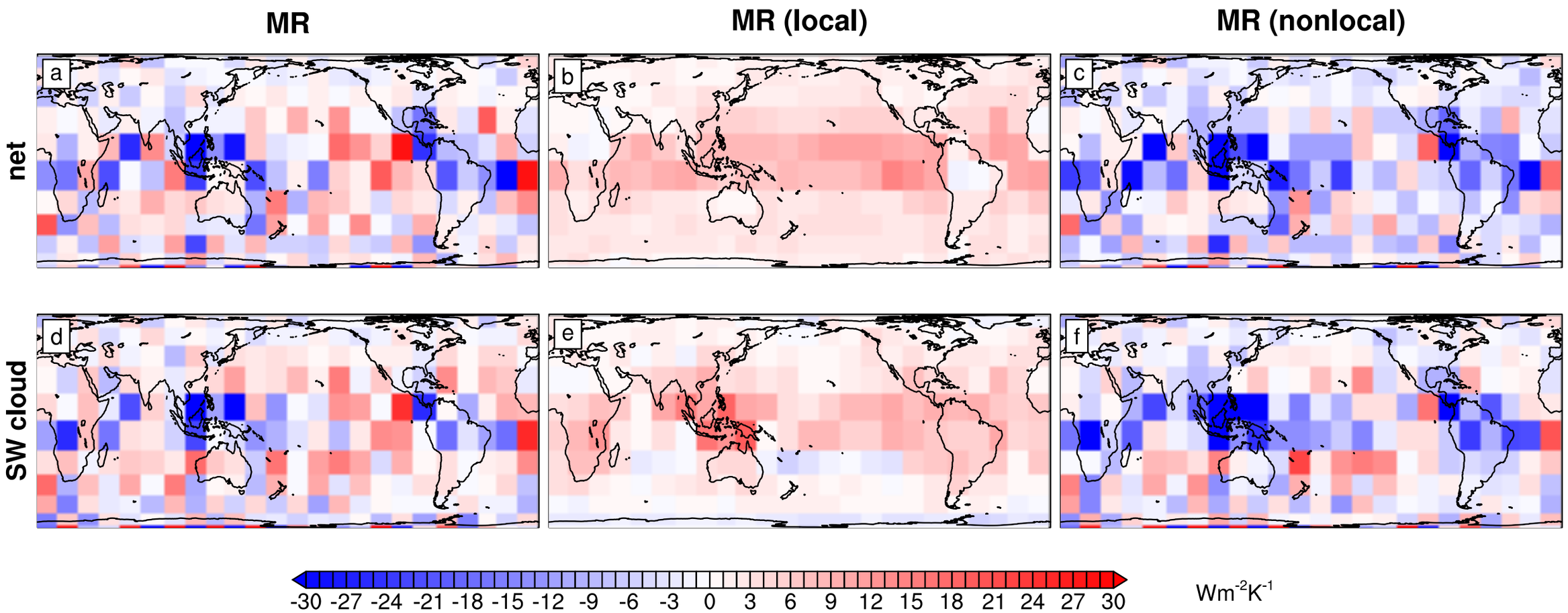
Dong et al., 2019



$$\vec{N} = \Lambda \vec{T} + noise$$

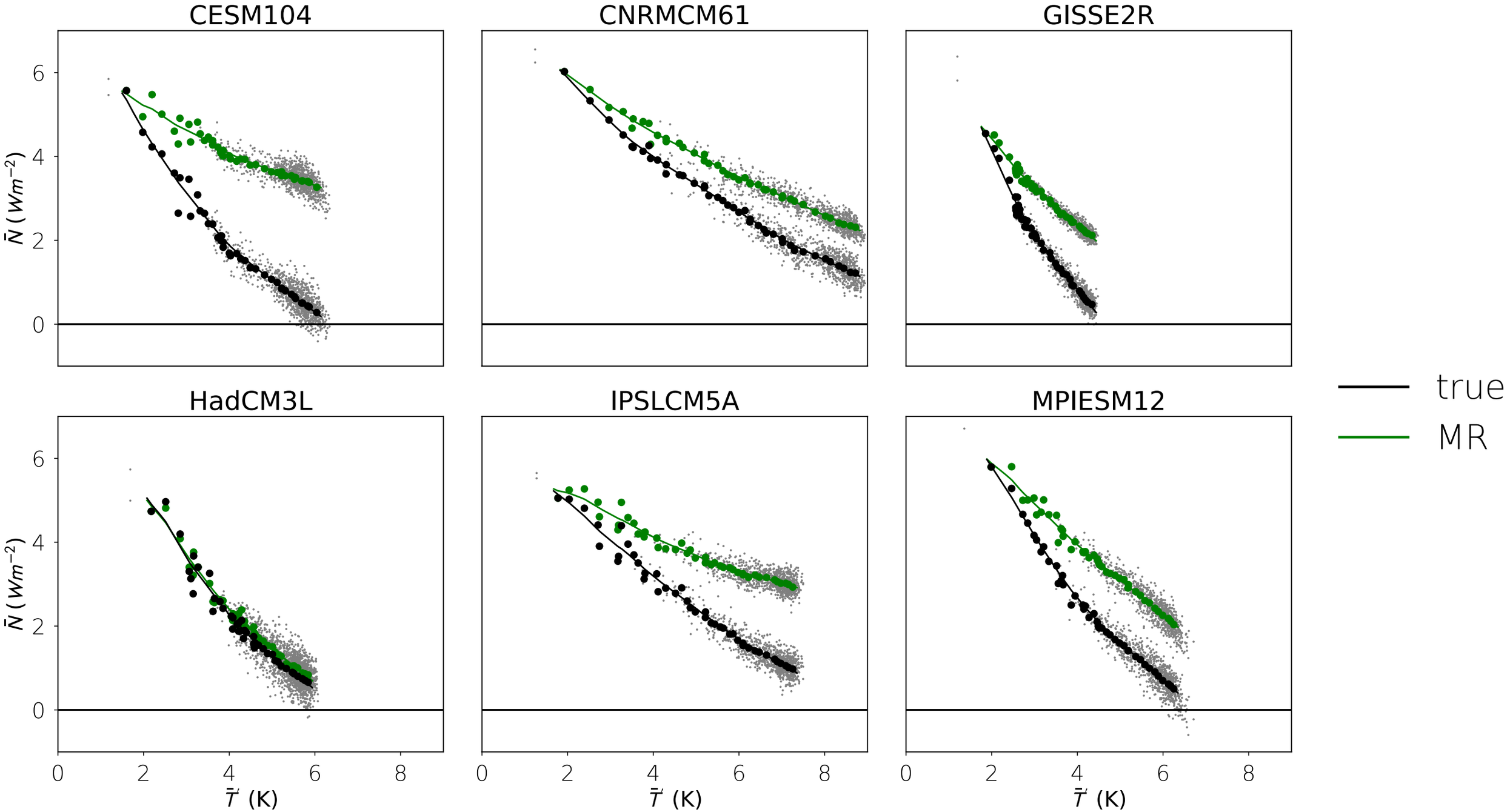


$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

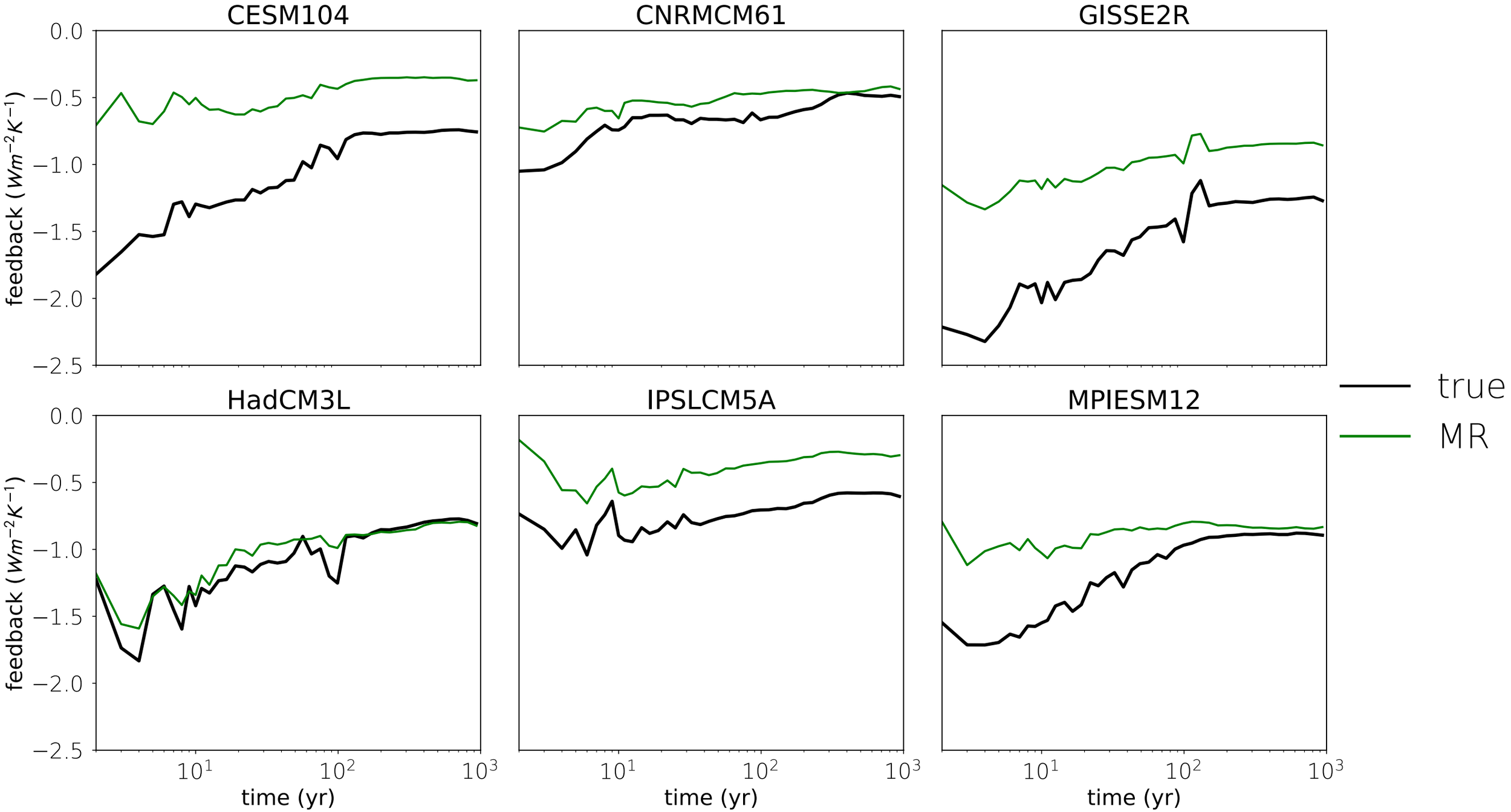


$$\overrightarrow{N} = \Lambda \overrightarrow{T} + noise$$

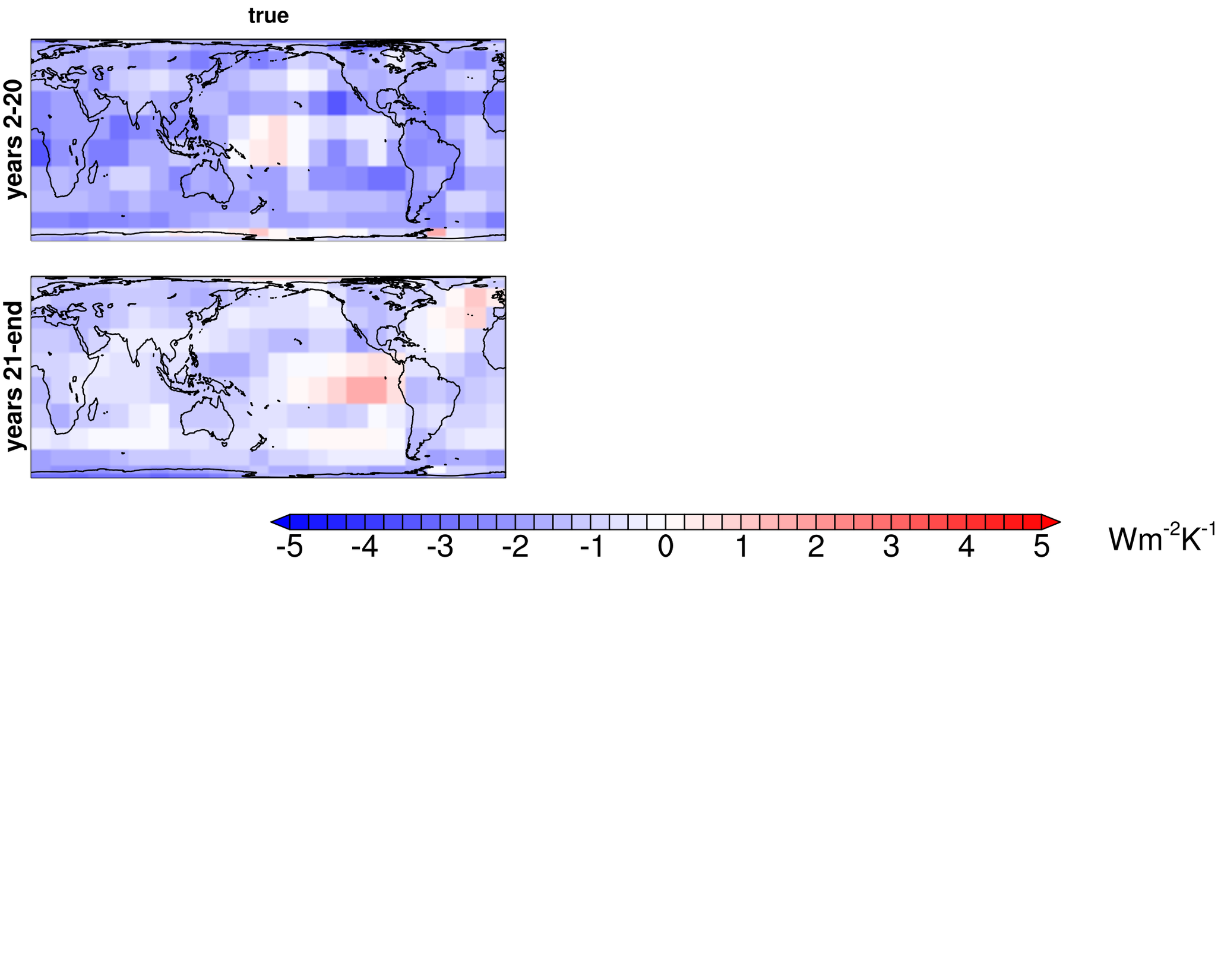
evolution of abrupt4x feedback



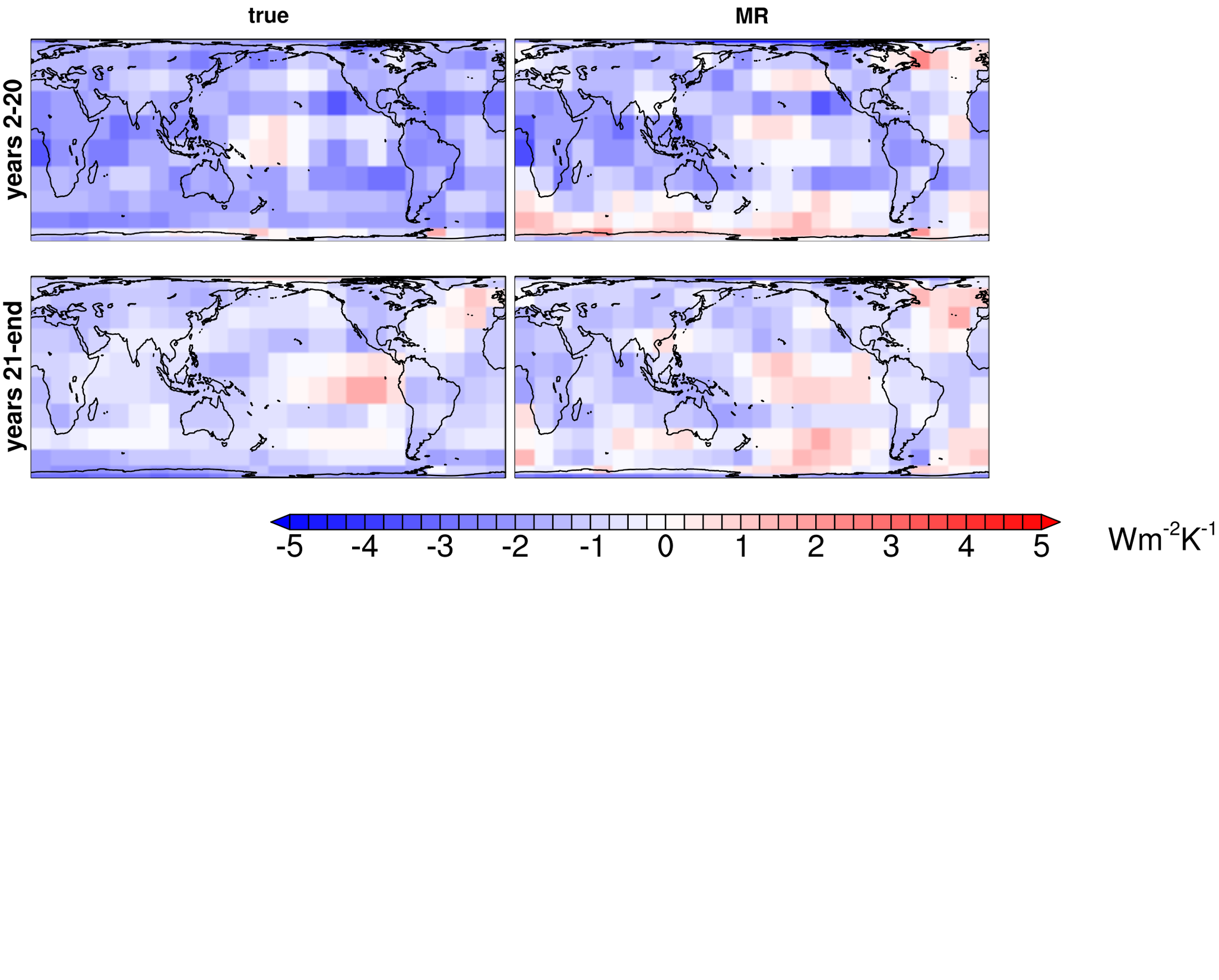
evolution of abrupt4x feedback



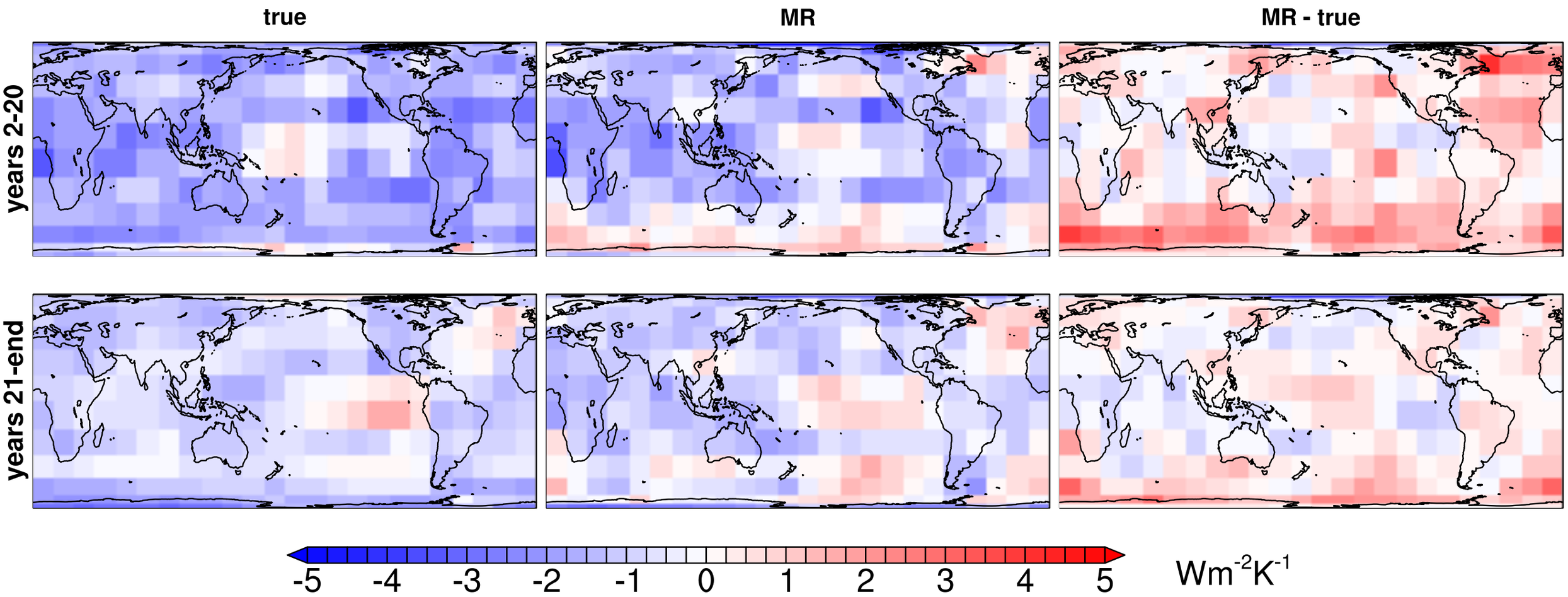
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x



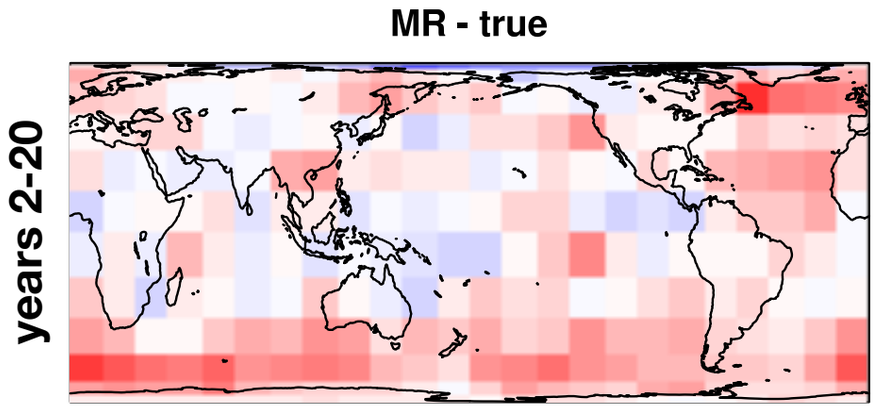
$\Delta \overrightarrow{N} / \overline{T}$ for abrupt4x



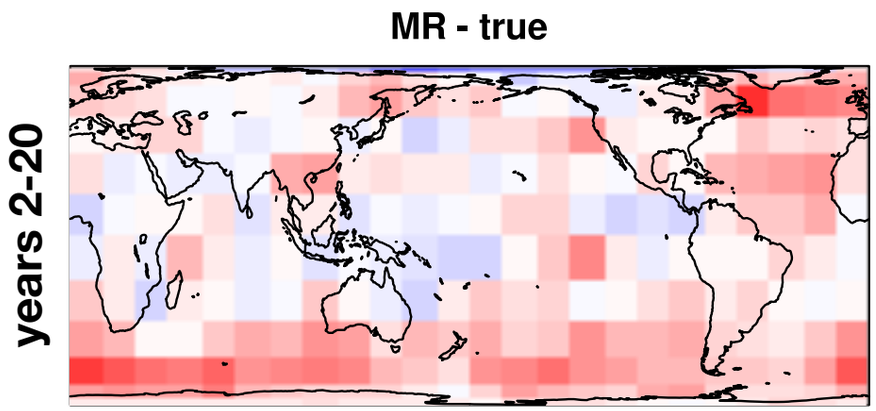
$\Delta \overrightarrow{N} / \overline{T}$ for abrupt4x

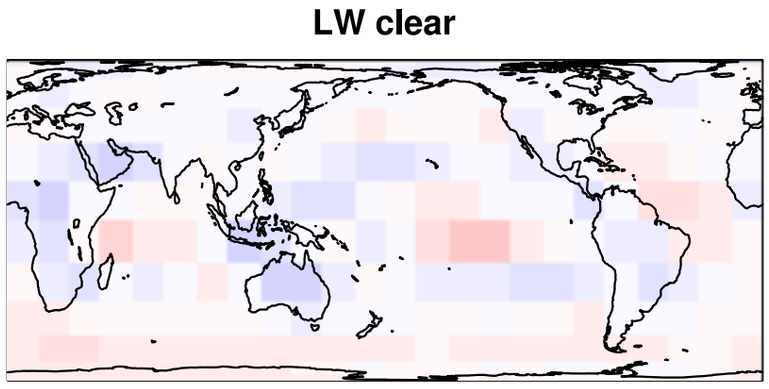


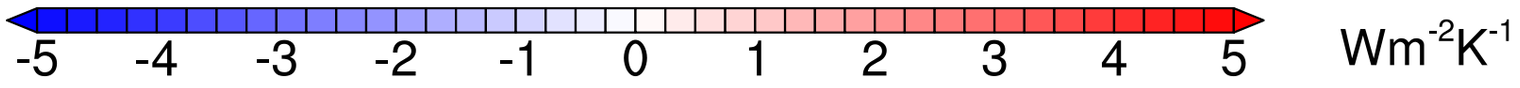
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x



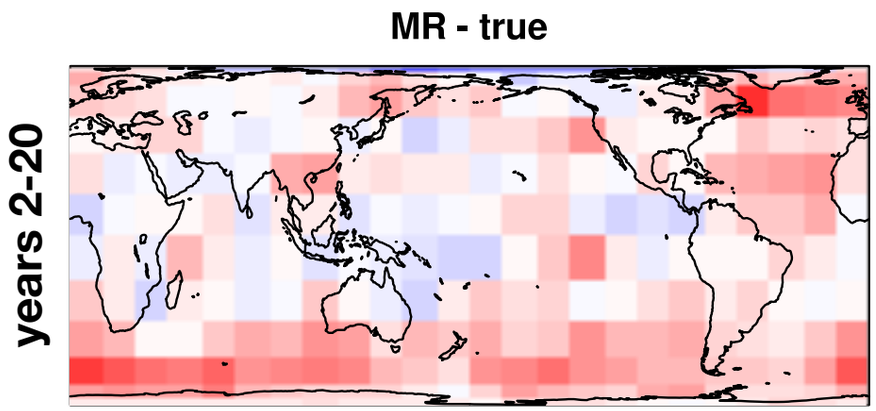
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x

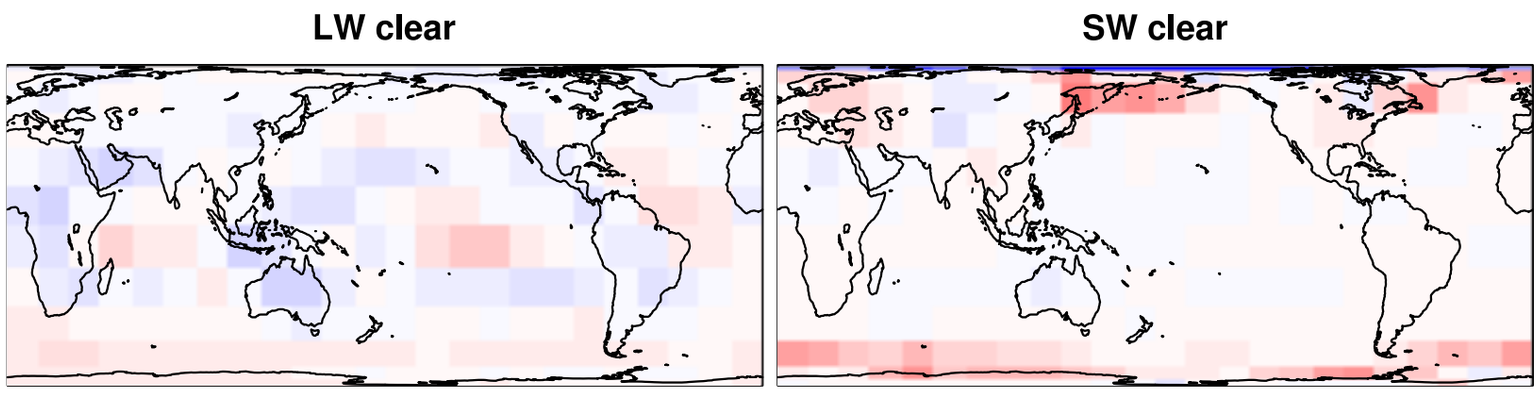


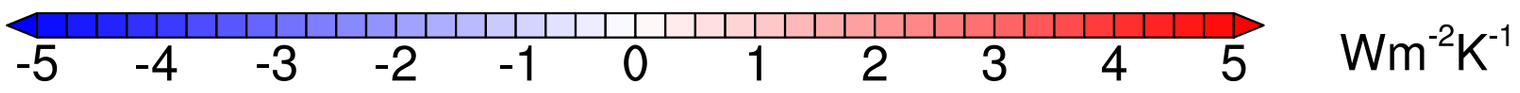




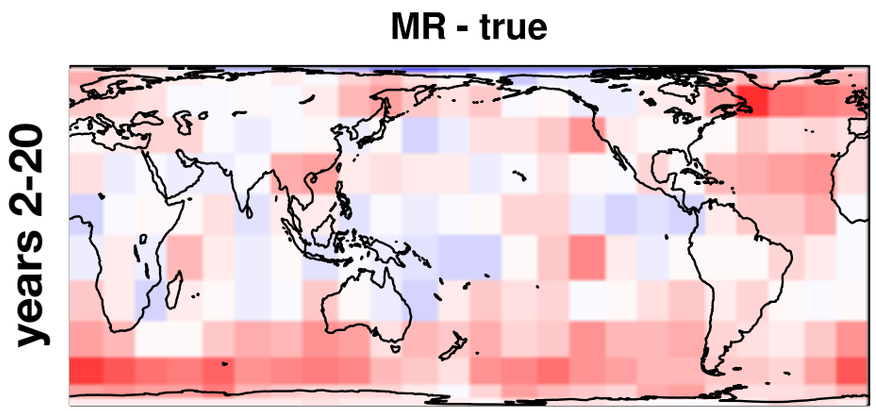
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x

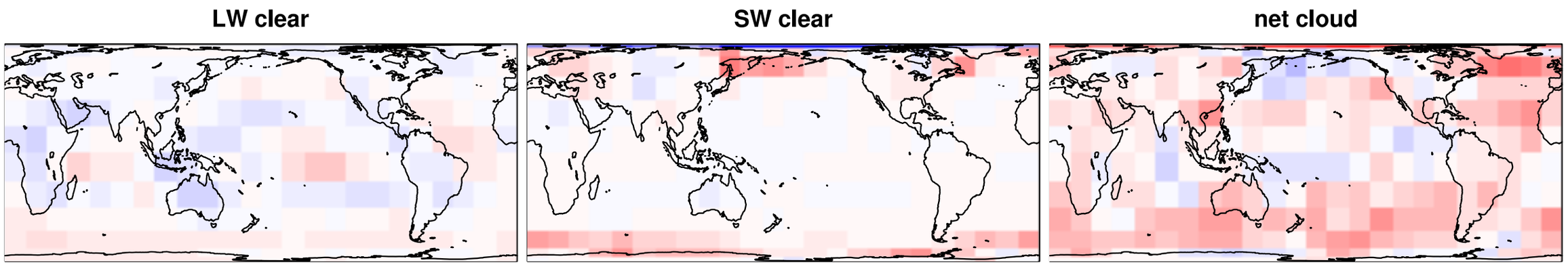


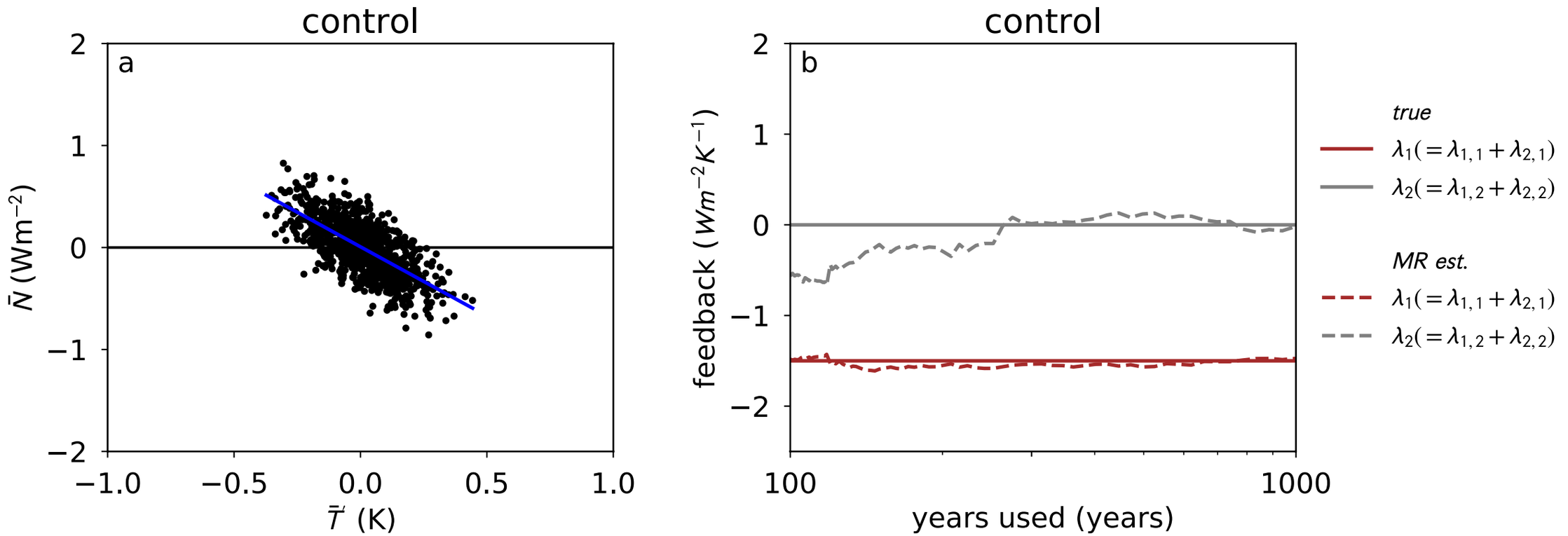


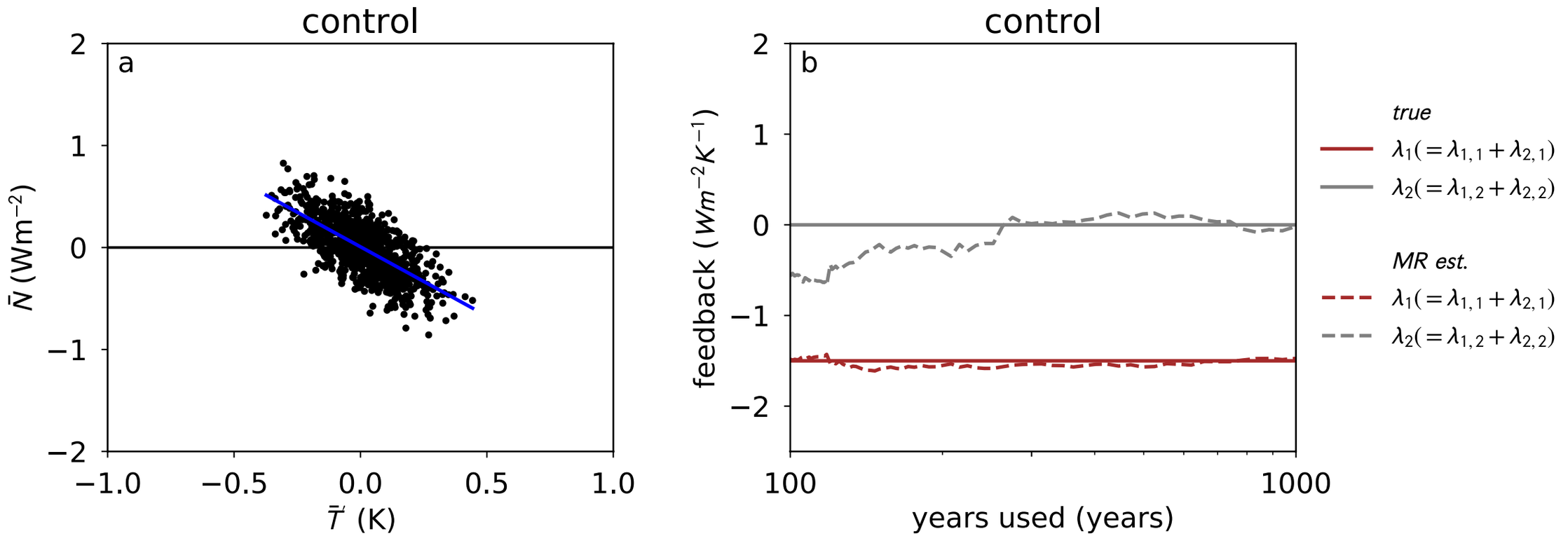


$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x

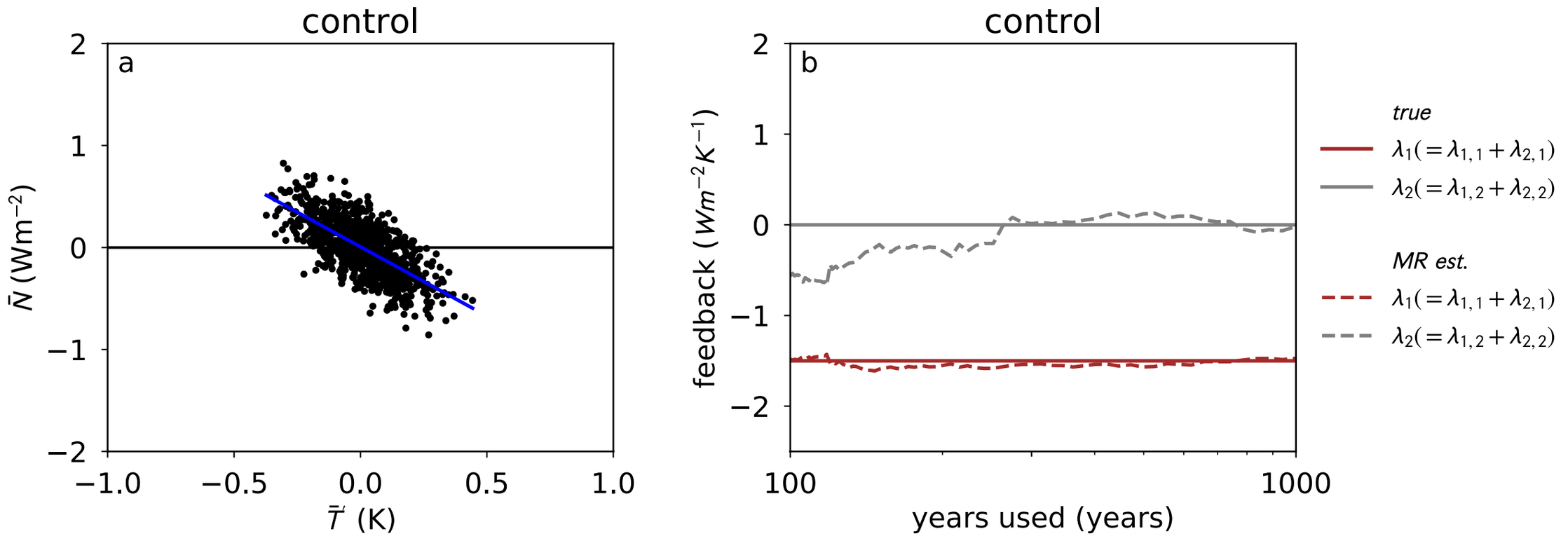





control
a
2
1
0
−1
−2
−1.0
−0.5
0.0
0.5
1.0
$\bar{N}$ (Wm^{-2})
$\bar{T}'$ (K)
control
b
feedback ($Wm^{-2}K^{-1}$)
100
1000
years used (years)
true
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$
MR est.
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$

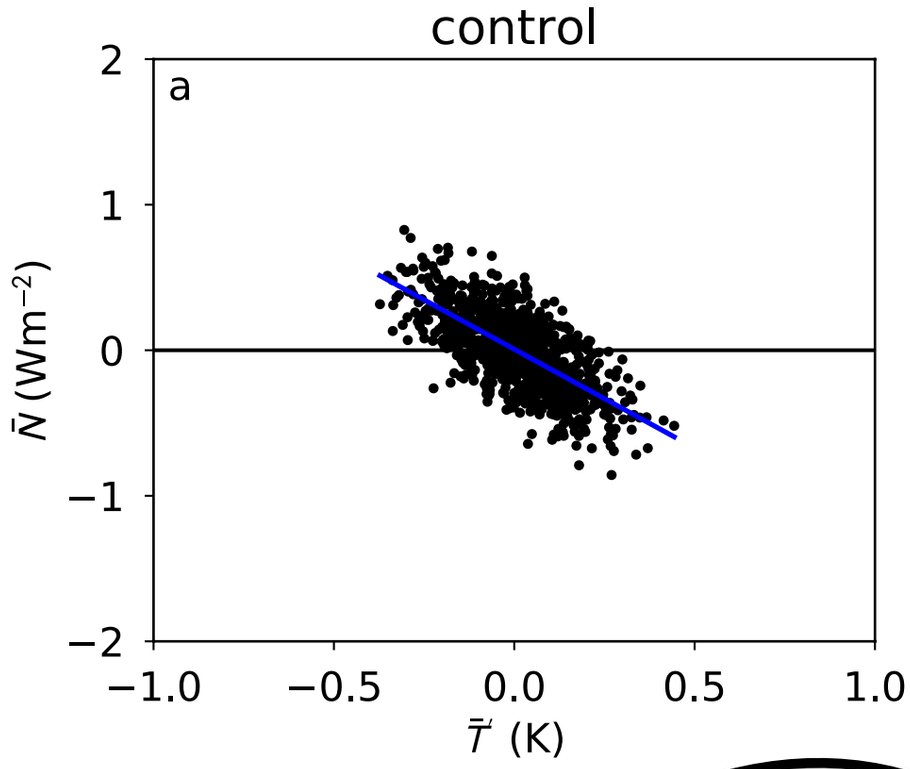


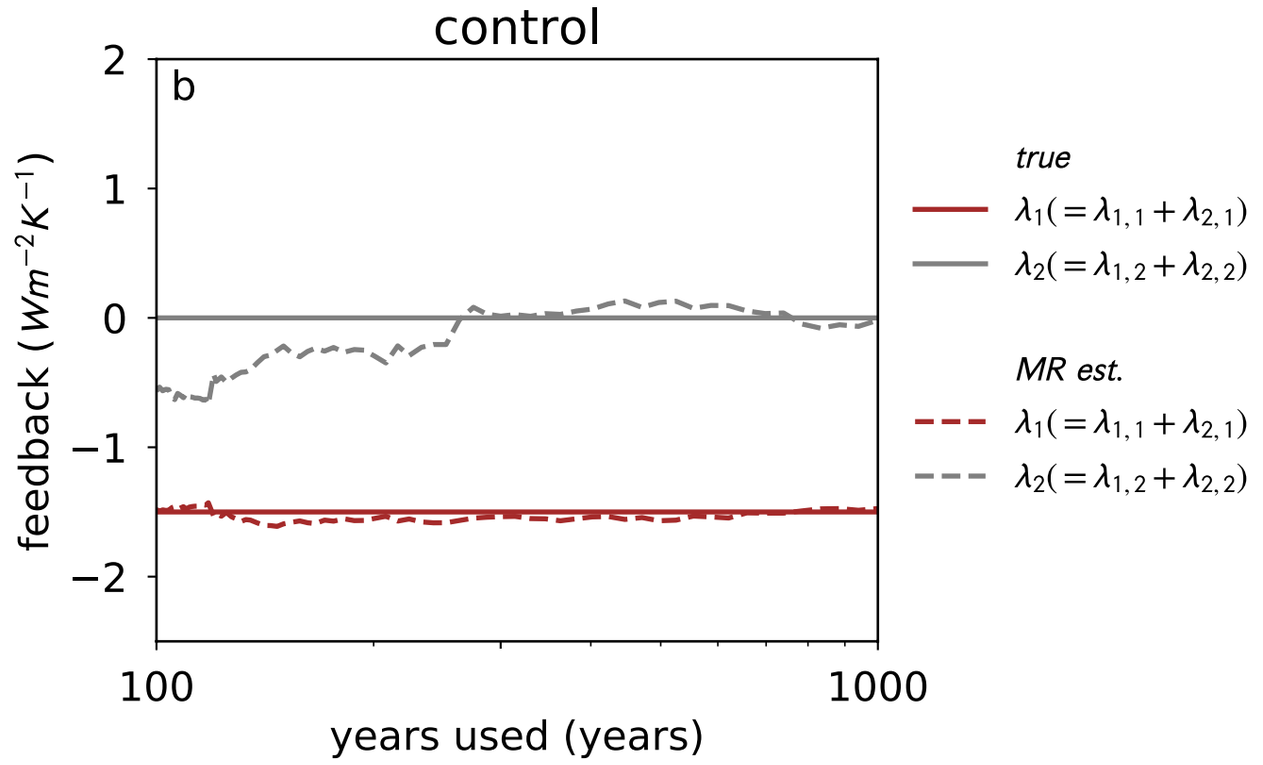
$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \underbrace{\Lambda \vec{T} + \vec{F}_{TOA}}_{\vec{N}} - H + \vec{F}_{surf}$$



$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \underbrace{\Lambda \vec{T} + \vec{F}_{TOA}}_{\vec{N}} - H + \vec{F}_{surf}$$

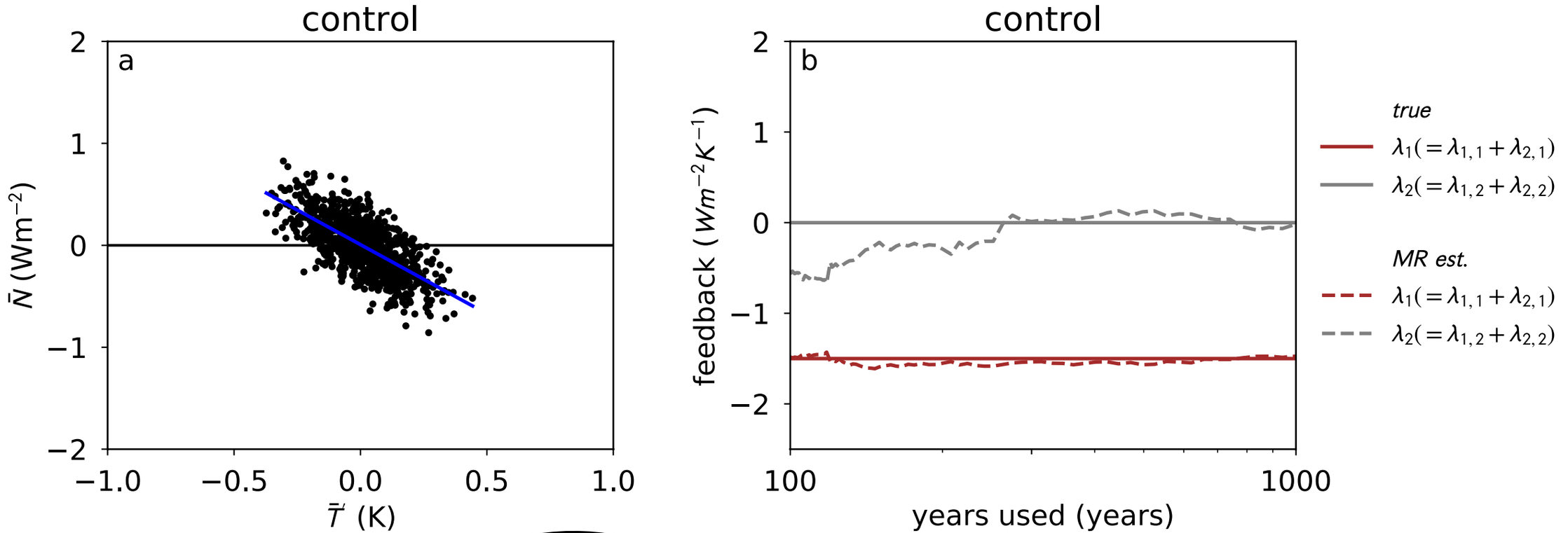
Proistosescu et al 2018





$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \underbrace{\Lambda \vec{T} + \vec{F}_{TOA}}_{\vec{N}} - H + \vec{F}_{surf}$$

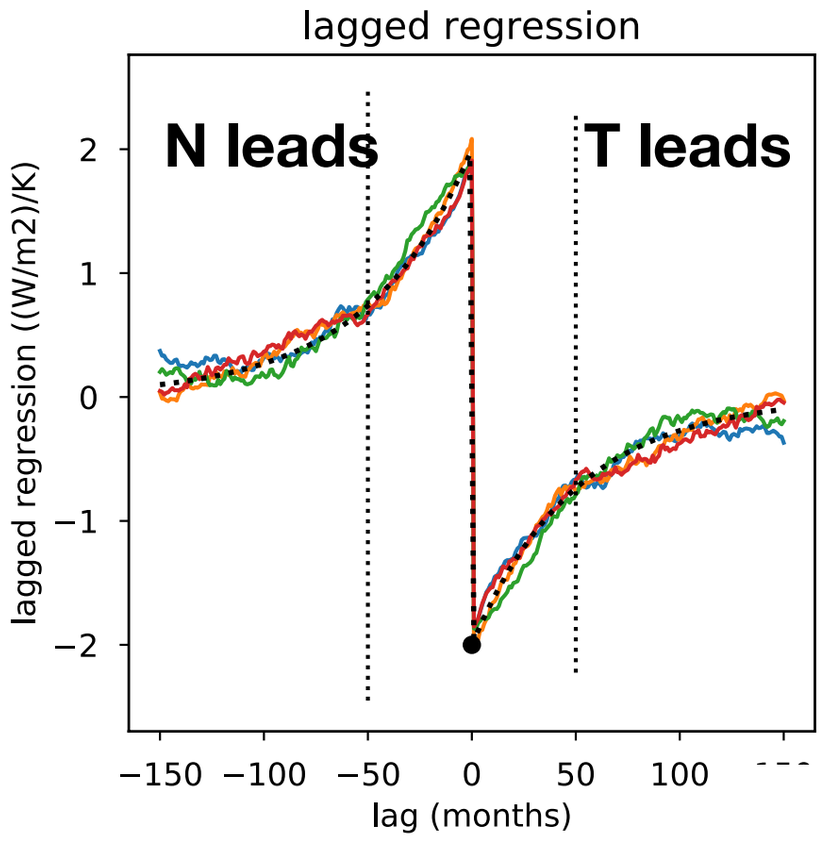
Proistosescu et al 2018



$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \Lambda \vec{T} + \vec{F}_{TOA} - H + \vec{F}_{surf}$$

$$\vec{N}$$

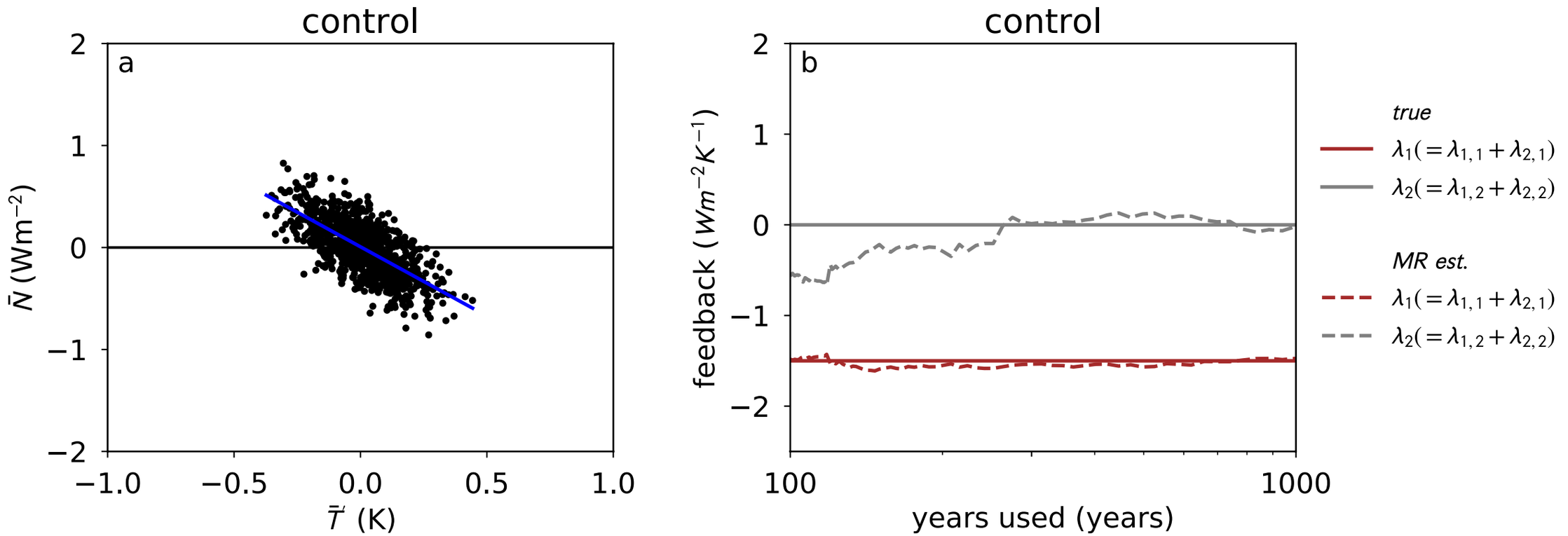
Proistosescu et al 2018



$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \Lambda \vec{T} + \vec{F}_{TOA} - H$$

$$\vec{N}$$

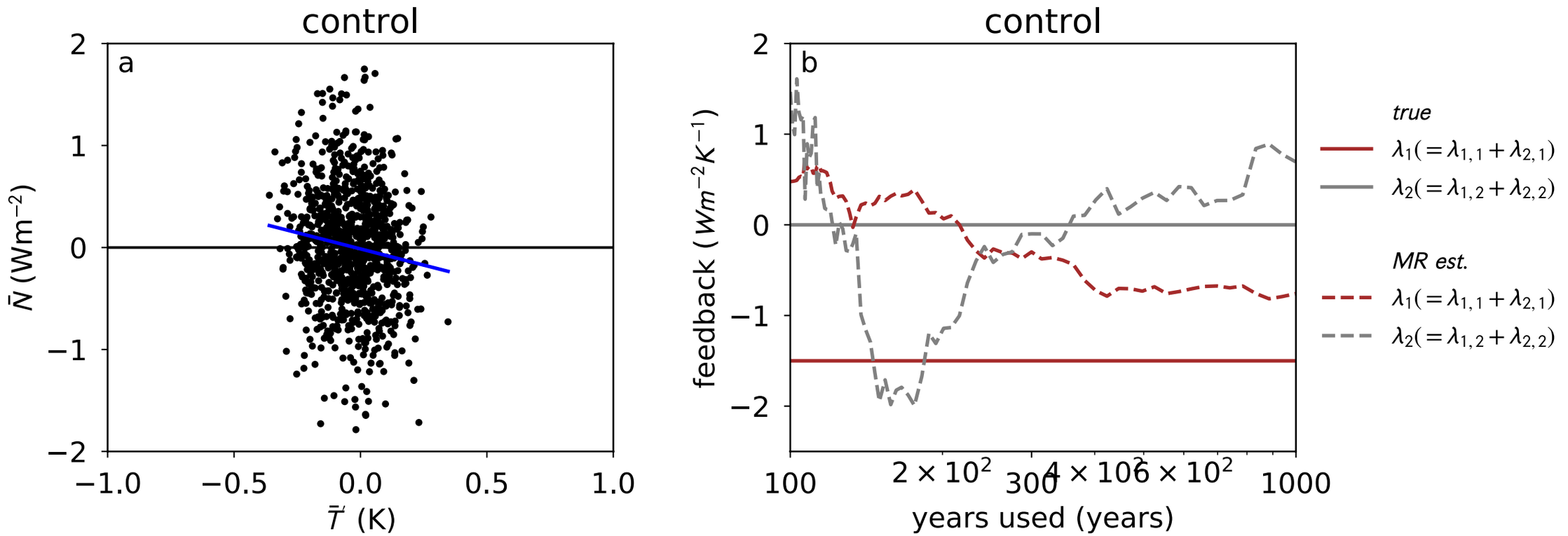
Proistosescu et al 2018



$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \underbrace{\Lambda \vec{T} + \vec{F}_{TOA}}_{\vec{N}} - H + \vec{F}_{surf}$$

5 Wm-2

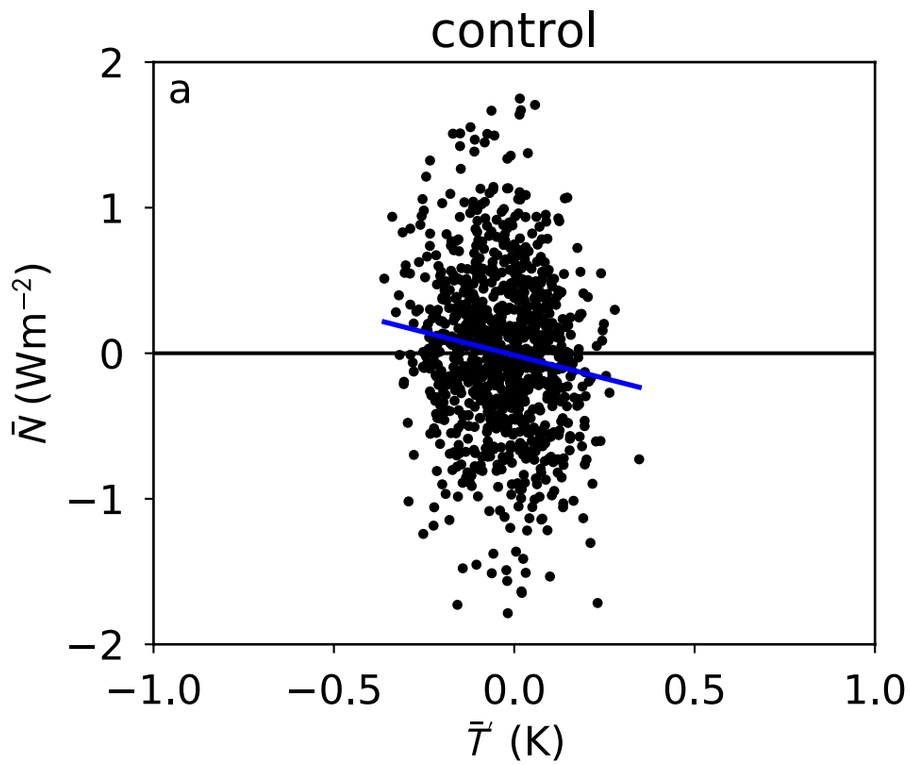
20 Wm-2

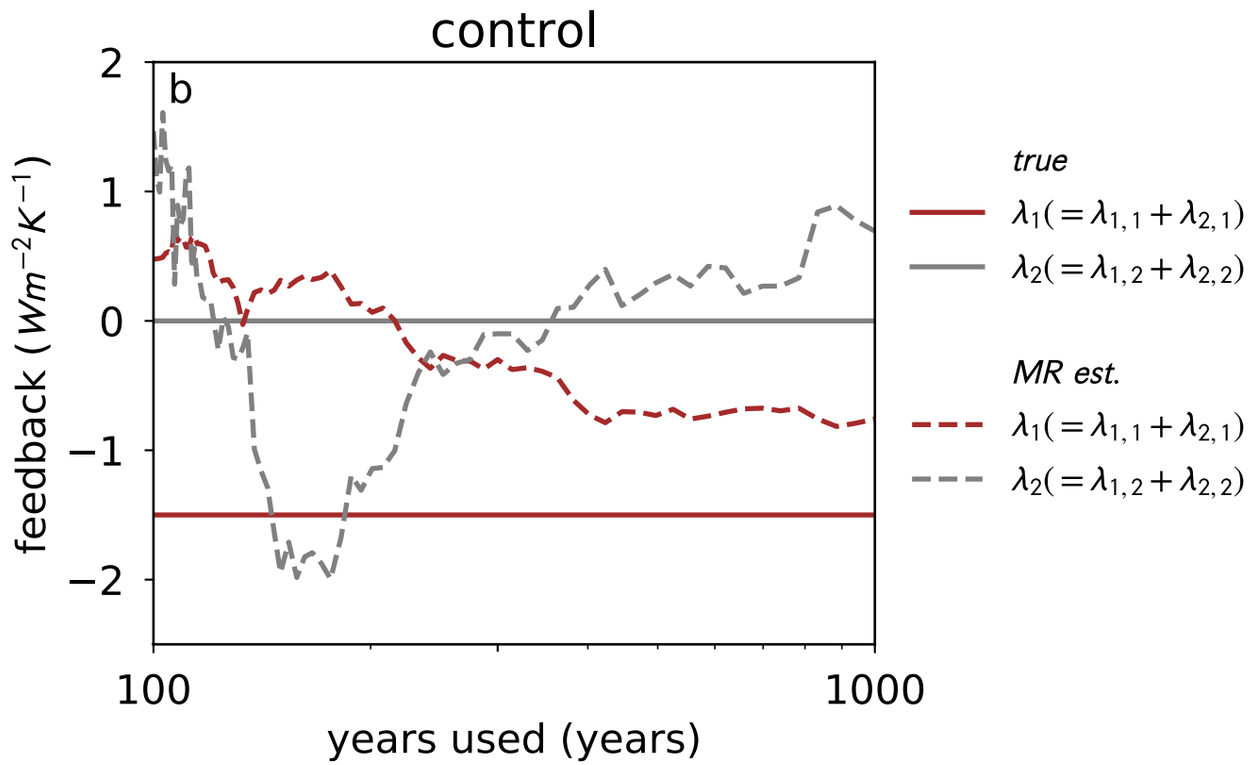


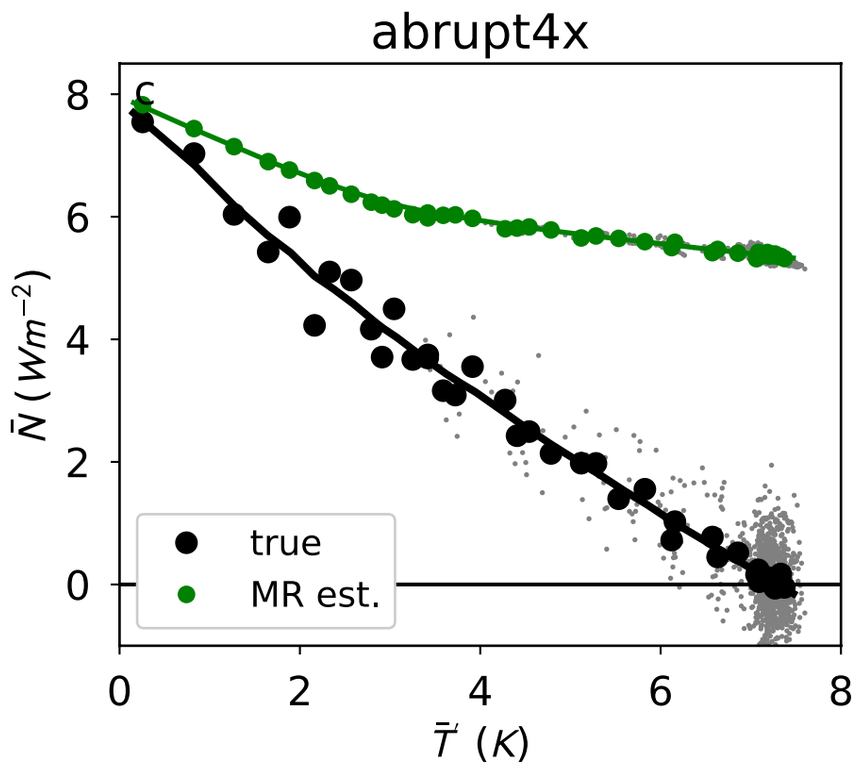
$$\vec{c} \cdot \frac{d\vec{T}}{dt} = \underbrace{\Lambda \vec{T} + \vec{F}_{TOA}}_{\vec{N}} - H + \vec{F}_{surf}$$

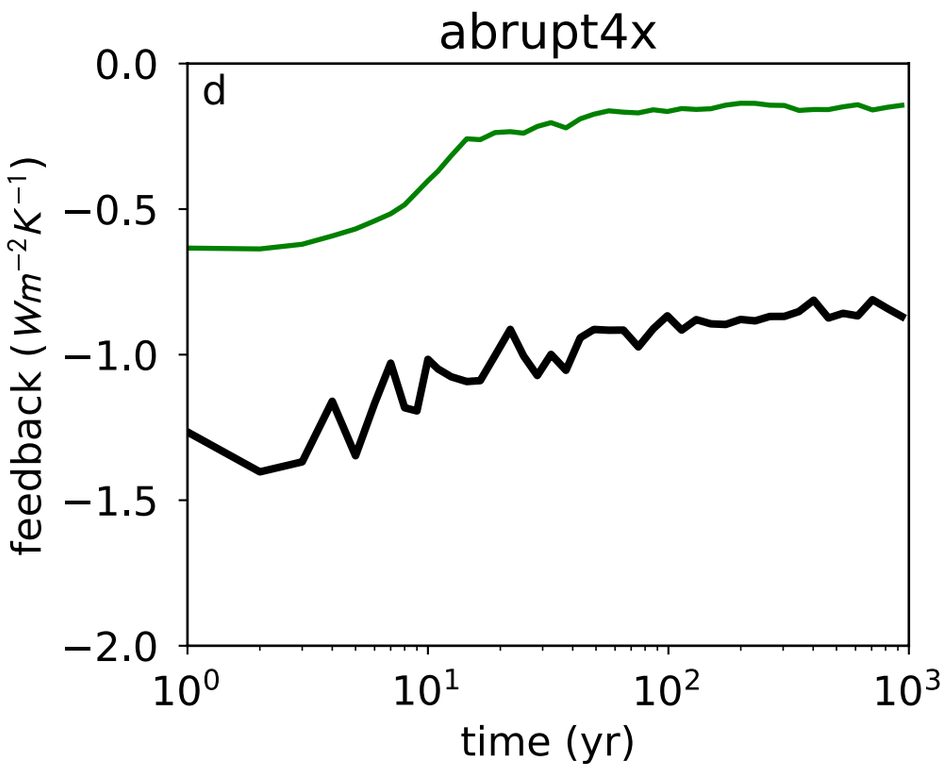
15 Wm-2

10 Wm-2

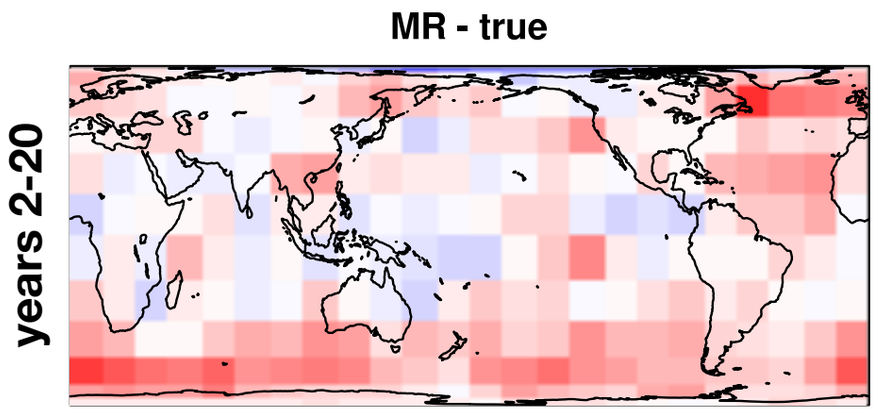

control
a
2
1
0
−1
−2
−1.0
−0.5
0.0
0.5
1.0
$\bar{N}$ (Wm^{-2})
$\bar{T}'$ (K)

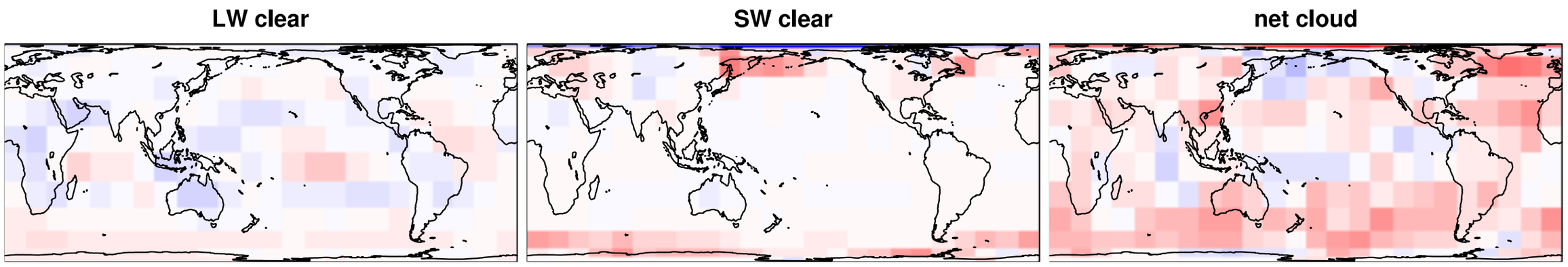

control
b
2
1
0
−1
−2
100
1000
feedback ($Wm^{-2}K^{-1}$)
years used (years)
true
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$
MR est.
$\lambda_1 (= \lambda_{1,1} + \lambda_{2,1})$
$\lambda_2 (= \lambda_{1,2} + \lambda_{2,2})$


abrupt4x
c
8
6
4
2
0
0
2
4
6
8
$\bar{N}$ (Wm^{-2})
$\bar{T}'$ (K)
true
MR est.


abrupt4x
d
0.0
−0.5
−1.0
−1.5
−2.0
10^0
10^1
10^2
10^3
feedback ($Wm^{-2}K^{-1}$)
time (yr)

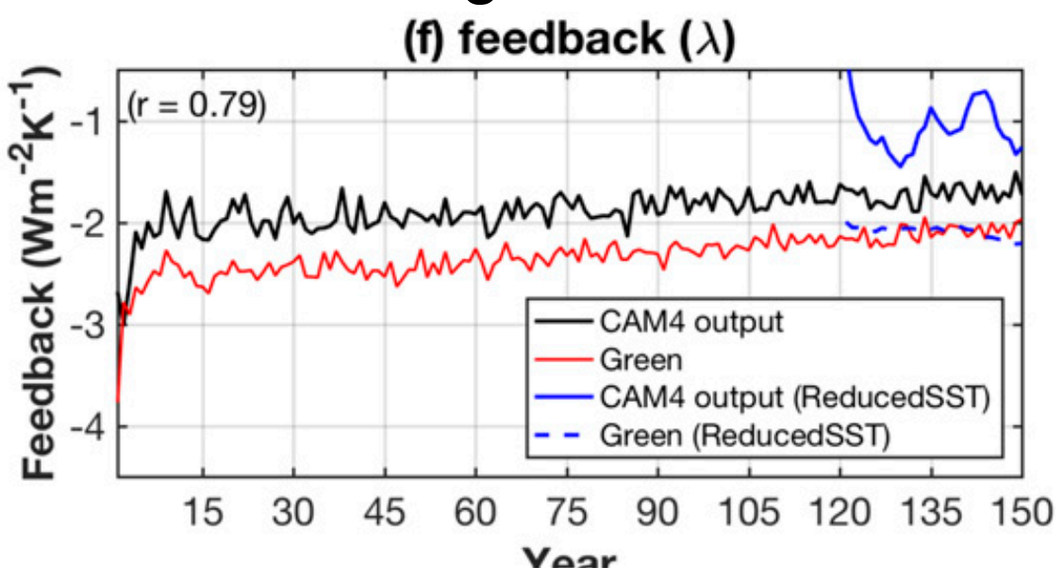
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x

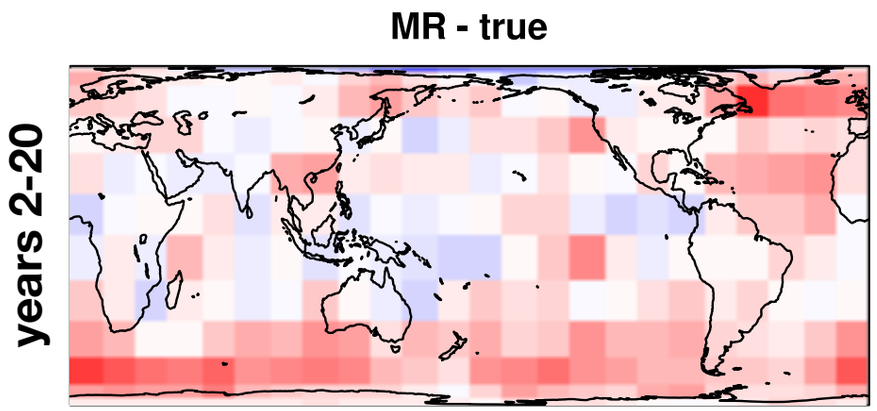




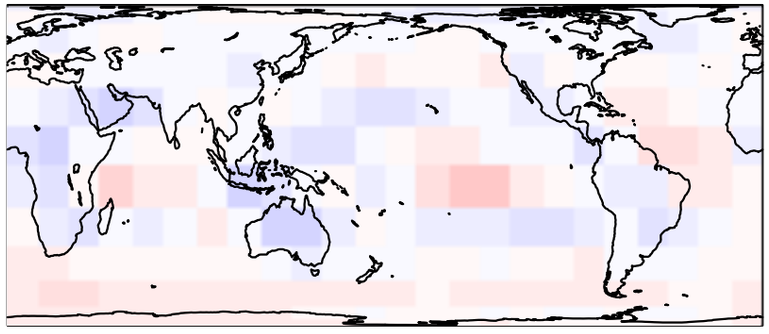
$\Delta \overrightarrow{N}/\overline{T}$ for abrupt4x

Dong et al. 2019

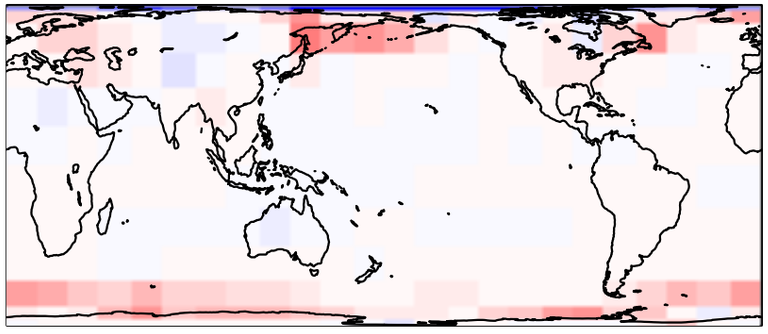




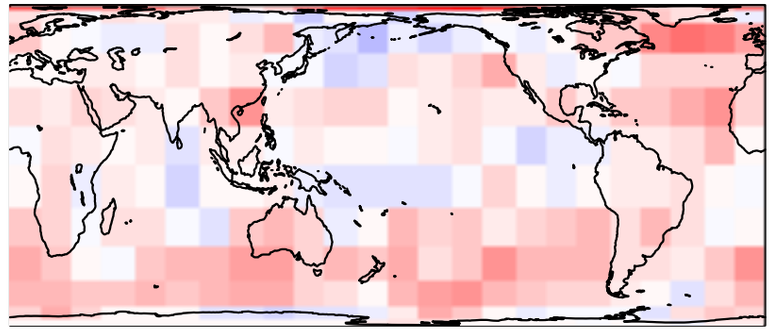
LW clear

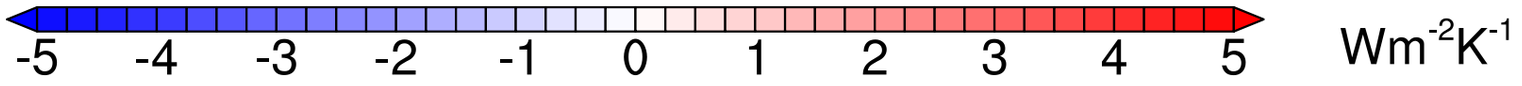


SW clear



net cloud





Conclusions

- Multiple regression method can be used to estimate spatial feedbacks from internal variability
- The MR method overestimates climate feedback due to anomalously high changes in TOA flux south of 30ºS
- Overestimate could be due to “regression dilution” or nonlinearity in Green’s functions - cause TBD